FAIRHEAT

Leathermarket JMB

Meakin Estate

Optimisation Business Case

22 October 2024

Meakin Estate: Optimisation Business Case

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1. Executive Summary

Meakin Estate is a housing development in Southwark, London owned by Leathermarket JMB. The development consists of 123 dwellings and was constructed in c. 1935, with more recent heat network refurbishments carried out in 2016.

Heating and hot water is generated locally by 2 Potterton Commercial gas boilers (c. 2.7 MW). Additional features of the heat networks include:

- There are four substations on the network, connected to the plant room via buried pipework. The hot water system is hydraulically separated from the primary circuit via plate heat exchangers (PHEs), whilst the space heating system is not hydraulically separated.
- Heat is distributed to all network connections via a 2-pipe network in the plant room, which splits into a 4-pipe network within each substation to feed dwellings.
- There are no Heat Interface Units (HIUs) on the network. Instead, the network directly feeds radiators and indirectly feeds hot water calorifiers, which are located within each substation to enable delivery of domestic hot water (DHW).
- Heat is also provided to communal radiators and hot water is provided to outlets in the community centre.

There are currently several key issues impacting the performance of the Meakin Estate heat network:

- The heat loss across the system is higher than would be expected from a well performing network, which is due to the 4-pipe, constant flow network arrangement.
- Fixed space heating and DHW bypasses are present across the network, with poor network insulation of low thicknesses, as well as bypassing radiators with limited space heating control. These issues contribute to significant heat losses and increased return temperatures.
- Plastic secondary network pipework presents several risks to heat supply reliability. Leaks are a known and consistent issue on site.
- The installation of DHW calorifiers and PHEs within substations are also constraining both the flow and return temperatures to greater than what is achievable for instantaneous DHW production.
- In the energy centre, oversized and poorly controlled equipment and pipework, as well as several hydraulic issues, lead to increased equipment wear, maintenance responsibility, and further heat losses.

The proposed options for performance improvements have been grouped into three proposed packages of works, which can be summarised as follows:

- Work Package 1 proposes to reduce return temperatures and heat losses across the network through recommissioning dwelling radiators, installing temperature control valves (TCVs) on the DHW network, and reinsulating all accessible pipework. In the plant room and substations, the BMS will be reinstated and recommissioning works are proposed for the boilers, pumps and DHW calorifiers. This will reduce heat losses, flow temperatures, gas and electricity consumption.
- Work Package 2 proposes to carry out a 4-pipe to 2-pipe network conversion, substantially reducing heat losses and return temperatures further. This includes the decommissioning of the DHW calorifiers and space heating network,

installation of single-plate HIUs, pressure-independent thermostatic radiator valves (PI-TRVs) and heating thermostats/programmers in dwellings and the community centre. For this solution, the secondary network pipework will be retained as a cost saving measure, however, this will retain the risk leak currently experienced on site. Additional hydraulic works will be undertaken in the plant room, along with the replacement of the network pumps, decommissioning of the dosing pot and installation of a side stream filtration unit. Boiler and pump recommissioning is also proposed, as in Work Package 1. Again, this will reduce flow temperatures, gas and electricity consumption and also minimise network heat losses and maintenance responsibility.

- Work Package 3 proposes to incorporate all of Work Package 2, with additional decommissioning of substation PHEs and replacement of dwelling/communal radiators, boilers and secondary network pipework. A new 2 pipe heat network will be retrofitted. Major replumbing works are also proposed within the energy centre, including the removal of the low loss header and installation of thermal stores and a network 3-port valve. This will further limit flow and return temperatures and heat losses, whilst improving boiler generation efficiency and flow temperature stability.

A limited number of key performance indicators (KPIs) can be calculated for the current performance of the heat network based on information provided, available heat meter data and data collected during the site audits. Table 1 sets out the current performance and outlines the improvement each KPI associated with each work package.

Type	Area	KPI / metric	Base Case	WP1	WP2	WP3	Unit
Performance	Energy Centre	Heat generation efficiency	80	80	80	90	%
		Average flow temperature	71	70	70	55	°C
		Average return temperature	63	60	60	40	°C
	Heat network	Heat network loss	1003	604	276	221	W/ dwelling
		Bypass flow rate	Data unavailable				%
		Average flow temperature	56[1] 54[2]	60[1] 65[2]	60	52	°C
		Average return temperature	52[1] 50[2]	50	50	38	°C
	Dwelling	Average VWART across all modes of operation	51	50	40	36	°C

Type	Area	KPI / metric	Base Case	WP1	WP2	WP3	Unit
Reliability	Energy Centre	Major outages (per 100 days, over 4 hours, non-PPM)	0.30	0.26	0.12	0.02	No.
	Dwelling	Reported interruptions and reductions (per 100 dwellings per 3 month period)	8.8	7.5	3.5	0.4	No.
		Maintenance frequency (per 100 dwellings per 3 month period)	8.8	7.5	3.5	0.4	No.
Financial	Resident	Year 1 required heat tariff	27.53	20.84	20.32	16.38	p/kWh
Carbon	All	Carbon intensity of heat delivered	0.683	0.514	0.501	0.403	kg CO_2 / kWh

Table 1: KPIs for the current performance compared to the expected performance after optimising according to each Work Package. [1]Average network temperatures for DHW circuit pipework. [2]Average network temperatures for space heating circuit pipework

A net present value (NPV) financial analysis has been performed to quantify the benefit of each work package to improve the systems. A timeline of 20 years has been used for the analysis. A discount rate of 3.5% has been used to calculate the NPV. Data from the Green Book Supplementary Guidance Tables 4 (electricity) and 5 (gas) has been used to model the fuel costs over the NPV period. Given the scale of uncertainty over future fossil fuel prices, there are multiple scenarios modelled using different future gas and electricity cost trends that may occur. A central and high energy cost assessment has been carried out, for each work package, to model the financial benefit in two different future scenarios.

The NPV assessment has been performed with a focus on 10- & 20-year timeframes following the implementation of the work packages. The Meakin Estate heat network is c. 8 years old. Therefore, these timeframes allow the full lifecycle cost of replacing end of life equipment to be considered. It should be noted that assumptions regarding energy prices and future scheme use are less accurate over longer time periods.

Given the issues seen with the secondary pipework during the site audit, the plastic secondary pipework is likely to fail within the next 2-3 years. Work Package 2 proposes to decommission the space heating network, retaining the existing DHW pipe for the 2 pipe heat network, whilst Work Package 3 involves a full network retrofit with steel LTHW pipework. Thus, the secondary network pipework will require replacement between Years 2-3 of the analysis period, where it is not part decommissioned/replaced as part of Work Package 2/3.

Due to the age and condition of the BMS and combined low loss header and air/dirt separator, this equipment is likely to fail within the next 5-10 years. All Work Packages propose to reinstate the BMS and a new air/dirt separator is to be installed as part of Work Package 3, with the removal of the low loss header. It is estimated that if either of these works are not carried out, the corresponding items will require replacement between Years 5-10 of the analysis period.

Also, the substation heat meters were not operational at the time of the site audit. Therefore, the heat meters require replacement with separate units in Year 1 of the analysis where they are not repaired initially as part of any Work Package.

The results are shown below in Table 2 and Table 3, for the cases without and with external HNES funding respectively.

	Work Package 1		Work Package 2		Work Package 3	
GBSG Scenario	Central	High	Central	High	Central	High
Client Capital Cost	£417,400		£1,157,200		£2,243,000	
10 Year NPV	-£17,900	£221,600	£141,500	£733,000	-£290,900	£361,100
10 Year IRR	2.6%	14.3%	6.5%	18.0%	0.0%	7.6%
20 Year NPV	£204,400	£553,500	£669,000	£1,549,800	£385,800	£1,358,000
20 Year IRR	8.8%	18.1%	11.2%	20.8%	6.1%	12.0%
Simple Payback (years)	9	5	7	4	10	6

Table 2: High level summary of NPV & IRR of proposed work packages without external funding

	Work Package 1		Work Package 2		Work Package 3	
GBSG Scenario	Central	High	Central	High	Central	High
Client Capital Cost	£208,700		£578,600		£1,211,000	
10 Year NPV	£190,800	£430,300	£720,100	£1,311,600	£741,000	£1,393,100
10 Year IRR	19.5%	42.2%	30.2%	51.2%	18.4%	30.1%
20 Year NPV	£413,100	£762,200	£1,247,600	£2,128,400	£1,417,800	£2,390,000
20 Year IRR	22.5%	43.2%	31.6%	51.6%	20.7%	31.4%

Simple Payback (years)	5	2	3	2	3	3

Table 3: High level summary of NPV & IRR of proposed work packages with external funding

Without external funding, only Work Package 2 produces a positive NPV over a 10- and 20-year period in both energy cost scenarios. Of all work packages, Work Package 2 achieves the most favourable NPV over the 20-year period and has the highest rate of return in both energy cost scenarios.

Works that improve the efficiency of the site would qualify for funding under the Heat Network Efficiency Scheme (HNES). If funding is secured, then 50% of eligible capital costs are recuperated from external funding streams. As a result of this, the simple payback time of the project will approximately half for all energy price scenarios.

It should be noted that the capital costs for replacing the radiators and boilers (in Work Package 3) are not eligible for funding under HNES and Leathermarket JMB will need to fund these separately if Work Package 3 is selected. As such, the costs of replacing radiators in dwellings and boilers in the plant room have been included within the total capital costs, however these specific costs are the only items which are not discounted by 50%.

For both the central and high cost scenarios, the NPVs increase substantially over both the 10- and 20-year periods for each work package, when accounting for funding. All work packages generate a positive NPV over a 20-year period in both energy cost scenarios. With funding, Work Package 3 now produces the most favourable NPV over a 20-year period in both energy cost scenarios. However, Work Package 2 retains the highest internal rate of return in both cost scenarios.

As all options will benefit notably when taking the HNES funding into account, it is recommended that this is pursued regardless of work package selection.

Work Package 1 provides the least performance benefit and generates the worst financial outcome in most cost scenarios. Therefore, FairHeat conclude this to be the least feasible solution if a long term, robust engineering solution is preferred, as it retains the risks associated with the plastic secondary network pipework and a 4-pipe system.

Despite generating the best financial outcome in most cost scenarios, Work Package 2 still presents the same leak risk that the plastic secondary network pipework presents. The works in this work package should only be considered as a short term solution if large investment into performance improvement is not possible for the next 1 or 2 years. Although it presents a solid financial investment, the risk associated with this Work Package will be elevated, and it is likely that the pipework will need replacing shortly after completion of the works. Although it could be considered a stepping stone towards full a retrofit, as detailed in Work Package 3, this approach may extend resident downtime further than necessary.

Although significant capital investment is required, Work Package 3 provides a much more robust solution from an engineering perspective and presents a financially viable investment. If Funding is received, Work Package 3 provides the most favourable NPV over 10 and 20 years. Therefore, FairHeat would be confident in this work package achieving a permanent long-term benefit to Leathermarket JMB and their residents. As Work Package 3 enables a reduction in flow temperature to improve the feasibility of heat pump installation and efficient heat generation, Work Package 3 is recommended.

Several works to mitigate water quality and other reliability risks have also been identified. These are not included in the NPV assessment as they do not have a direct financial impact, but it is recommended that these are all implemented to ensure the optimisation opportunities identified can be realised.

In order to effectively deliver the identified works, it is recommended that stabilisation measures and easy wins are implemented first, prior to the roll out of the more intrusive works. The procurement route should be confirmed as soon as possible as this is commonly a barrier to effective project deployment.

The total capital cost of all performance improvement and risk mitigation works is summarised in Table 4. All costs are presented excluding VAT.

	WP1	WP2	WP3
Water quality works	£7,000	£7,000	£7,000
Recommended other considerations	£34,000	£34,000	£34,000
Performance improvement works	£203,000	£656,000	£1,360,000
Cost of design, engineering support & delivery	£165,000	£364,000	£618,000
Sub-total	**£409,000**	**£1,061,000**	**£2,019,000**
Contingency & inflation	£55,000	£142,000	£270,000
Total	**£463,000**	**£1,203,000**	**£2,289,000**
Costs not eligible for HNES funding	-	-	£179,000
HNES funding available (46-50% of eligible costs)	£231,000	£601,000	£1,055,000
Total with HNES funding	**£232,000**	**£602,000**	**£1,234,000**

Table 4: Total cost of all risk mitigation and performance improvement works

Contents

2. Introduction

Meakin Estate is a housing development in Southwark, London owned by Leathermarket JMB. The development consists of 123 dwellings and was constructed in c. 1935, with more recent heat network refurbishments carried out in 2016.

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- Heat is distributed to all network connections via a 2-pipe network in the plant room, which splits into a 4-pipe network within each substation to feed dwellings.
- There are no Heat Interface Units (HIUs) on the network. Instead, the network directly feeds radiators and indirectly feeds hot water calorifiers, which are located within each substation to enable delivery of domestic hot water (DHW).
- Heat is also provided to communal radiators and hot water is provided to outlets in the community centre.
- There are no other commercial/retail units connected to the network.

A map showing the location of each block has been set out within and an indicative location of heat network distribution pipework to the building risers has been shown below in Figure 1.

The purpose of this document is to determine the root causes of system issues and undertake a techno-economic assessment of potential heat network optimisation opportunities. Findings are based on two site audits undertaken on 6th and 20th June 2024 and additional site information and data provided by Leathermarket JMB.

This report has been completed in line with a Phase 1-3 assessment as defined in the *Department for Energy Security & Net Zero Heat Network Optimisation Guide (HNOG),* which was produced by FairHeat in 2023. A summary of the optimisation study process followed is outlined in Appendix 1 – Optimisation study process overview.

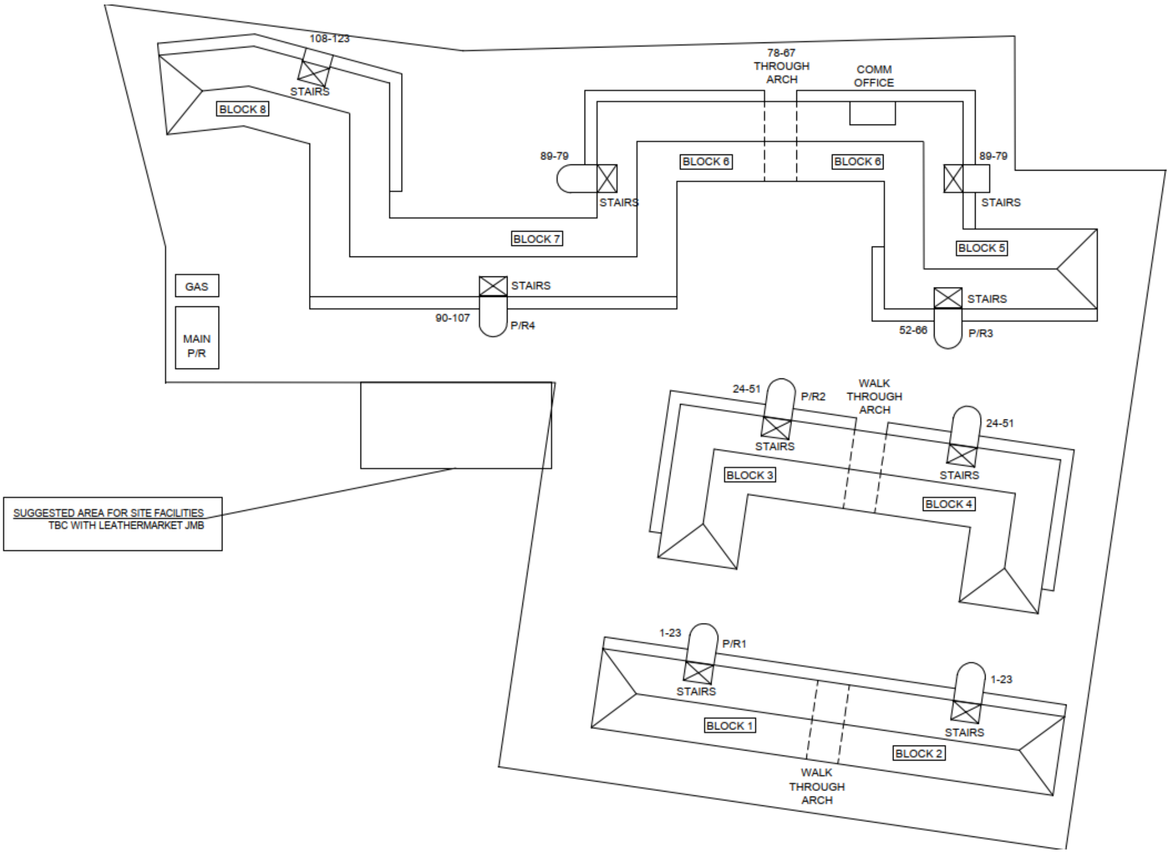

Figure 1: Layout showing location of buildings, plant room, substations and each block

3. Optimisation study principles

The *Department for Energy Security & Net Zero Heat Network Optimisation Guide,* which was produced by FairHeat, outlines several key principles for optimising heat network performance which have been followed in this report. These principles emphasise the importance of continuous improvement, the hierarchy of importance of each section of the heat network and the approach to improving poorly performing equipment.

3.1. Principles for improving performance

When approaching the challenge of improving the performance of a heat network, it is important to develop and follow a clear process. Without a clear methodical approach to the project, it can be challenging to determine the progress of the project and what outputs are expected at each stage.

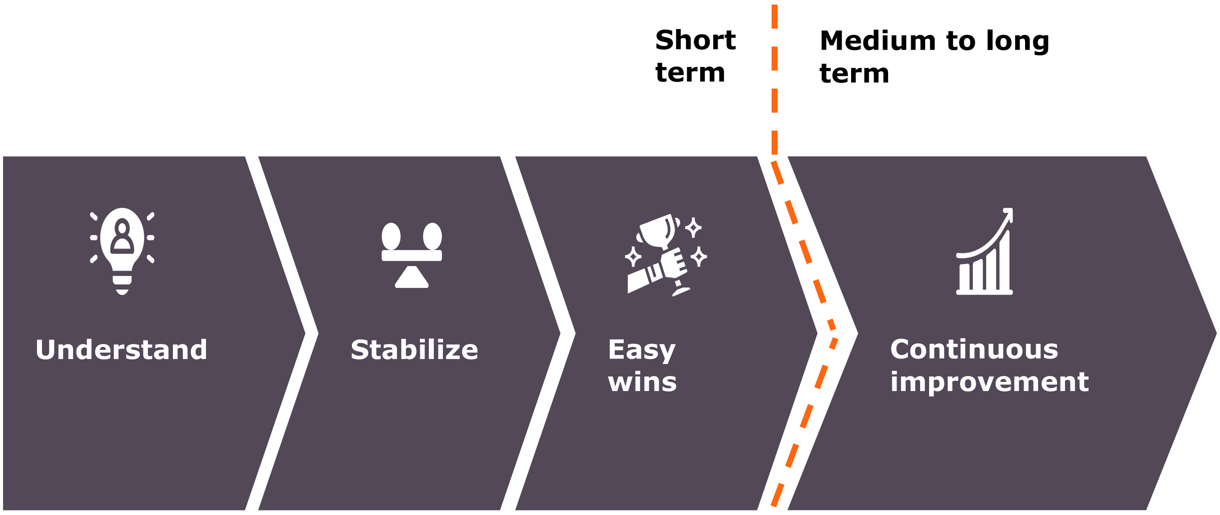

Figure 2: Phased approach to optimising heat network performance.

When assessing a poorly performing heat network, a phased approach is required to ensure that urgent issues are addressed prior to considering the long term optimisation of the network.

The first stage of improving performance is to understand the underlying issues with a network. Once the root cause of the issues have been identified then it may be necessary to stabilize the heat network. In this context, stabilizing refers to measures that can be undertaken very quickly and that will have immediate and large impacts on heat network performance and reliability.

Once the heat network has been stabilized then a series of quick, easy win measures should be carried out. These are typically interventions that have very short implementation and payback times but require more planning and design input.

Once the system has been stabilized and the easy wins implemented then the performance should be improved further and the system made more reliable. In the longer term plan for the heat network, a continuous improvement approach is required.

The aim of continuous improvement is to ensure that there is an ongoing effort to incrementally improve the performance over the longer term. As shown in Figure 3, the steps in the continuous improvement cycle are as follows:

1. **Measure:** Without being able to measure network performance, it is challenging to evaluate and validate the impact of potential interventions. For the continuous improvement process to be effective, there needs to be a method of extracting operational data either on site or securely via the internet.

2. **Analyze:** Once collated, data can be used to assess potential optimisations.

3. **Test:** Potential measures can be tested (piloted) on a smaller sample to assess their effectiveness. For example, HIU replacement could be tested on a small number of flats to confirm the improvements in performance, or in larger networks, measures can be tested at a whole block level.

4. **Implement:** If testing shows that the intervention measures have the desired effect then then they can be implemented throughout the heat network.

1. **Measure** (the continuous improvement cycle repeats): The network data can be monitored post-implementation to confirm desired outcomes have been achieved and identify other areas where network performance can be improved.

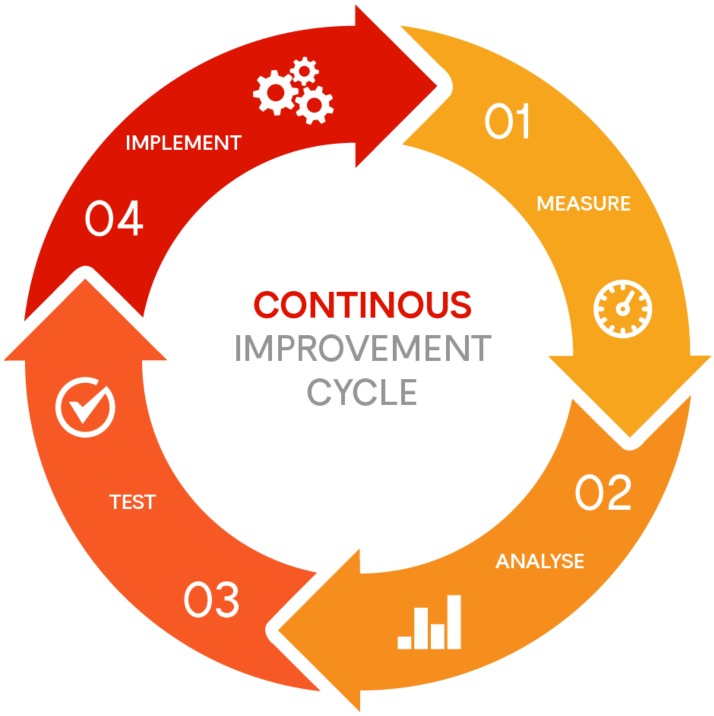

Figure 3: Continuous improvement cycle

Through adopting the continuous improvement cycle, network performance can be gradually optimised. Therefore, while optimisation studies may recommend a large number of measures, they will typically be delivered over a number of years and may adapt subject to the impact of initial interventions and resources of the operator.

3.2. Optimisation Hierarchy

The Optimisation Hierarchy (Figure 12) provides a guide for approaching heat network optimisation. It states, in order of importance to heat network performance, consumer heating systems are the most critical, followed by the district/communal distribution system with the energy centre being of least importance.

When approaching heat network optimisation, it has been common to consider the energy centre (plant room) as the main driver of the system efficiency. However, while the energy centre contains the largest and most complex equipment in the system, it can only have a limited impact on the network heat losses.

Contrary to this approach, the requirements and performance of consumer heating systems (e.g. dwellings) are the most important aspect affecting the overall performance of the heat network. End user requirements dictate the minimum flow temperature that the entire network can operate at, and the end user equipment performance defines the minimum return temperature throughout the system.

The minimum flow temperature that the network can operate at is typically constrained by higher of the:

- Temperature required to generate domestic hot water for dwellings
- Temperature required to generate sufficient space heating output for dwellings (typically the constraining temperature)

Other constraints can include equipment and pipe sizes that cannot provide the required peak heat demand at lower flow temperatures. However, it should be noted that a combination of historic system oversizing and potential incremental improvements in fabric performance of the end user buildings means that there are usually opportunities to reduce flow temperatures.

Consumer connections and heating systems (such as HIUs and space heating emitters) also have a direct impact on the district/communal distribution return temperatures.

Minimising both flow and return system temperatures (while maintaining required performance) results in the lowest possible heat losses across the entire heat network. As the minimum flow and return temperatures are largely set by dwelling equipment, they are the most important element to optimise to achieve an efficient heat network.

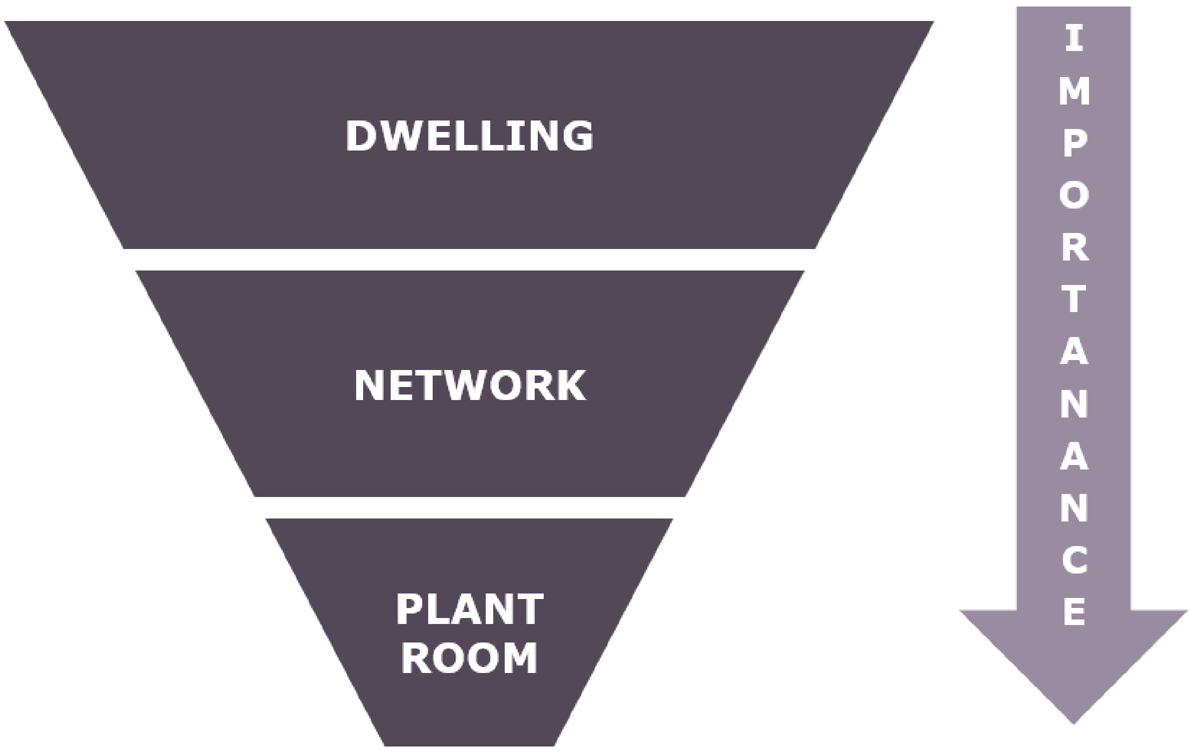

Figure 4 Optimisation Hierarchy for a residential heat network

3.3. Approach to improvement

When sub-optimal performance has been identified, it is recommended that the following approach to assessing what approach measures are suitable are taken:

- **Repair**: the first consideration should be whether the equipment is faulty. If faulty equipment is identified, an assessment should be carried out to evaluate whether repairing the equipment will provide optimised performance. This may be done through a limited set of pilot works, particularly where the fault is identified in equipment that is installed in many locations (e.g. HIUs).
- **Recommission**: if the sub-optimal performance is not a result of faulty equipment, then the system should be recommissioned. As with Repair, undertaking the recommissioning in detail on a smaller number of pilot units would be beneficial to allow for assessment of the measures as it may be that, once full recommissioning has been carried out, the performance is still not considered adequate.
- **Upgrade/Improve**: once the equipment has been repaired and/or recommissioned, if the performance is still sub-optimal then an investigation should be undertaken as to whether the equipment could be upgraded or improved. This might be a smaller sub-element of a larger system that would reap large benefits, such as installing an inverter on distribution pumps.
- **Replace**: after all other approaches have been exhausted, if the system is still not performing sufficiently well then the equipment will need to be replaced.

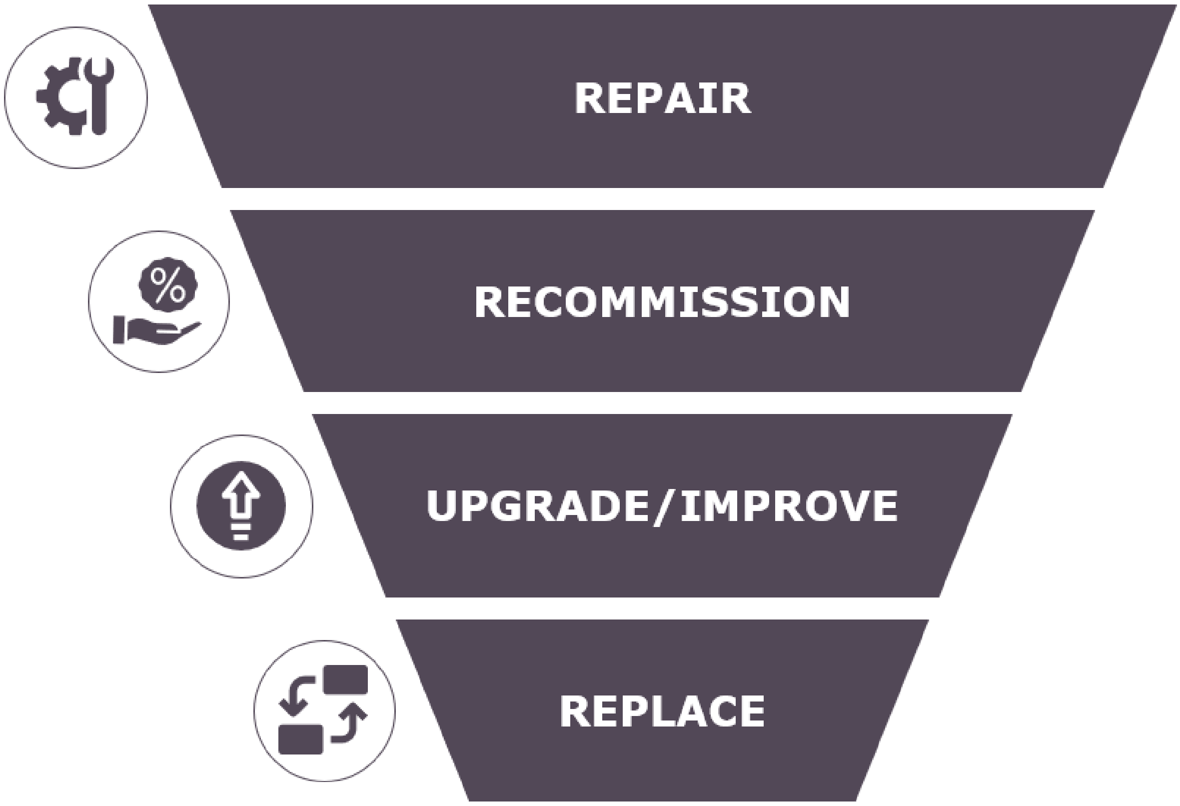

Figure 5: Approach to optimisation improvements

3.4. Key performance indicators (KPIs)

Heat network performance should be analysed and determined quantitatively to enable detailed assessment of potential interventions and to enable heat network operators to compare performance across their portfolio and prioritise systems for improvement.

By further setting out targets for each of the KPIs, it can help the heat network operator and its subcontractors to work proactively with performance issues.

FairHeat have a standardised set of KPIs selected as they are considered to give a holistic understanding of the performance of a heat network and help facilitate analysis of issues and proactivity of maintenance. The value for each KPI has been determined based upon the information obtained from the on-site audits and/or data supplied by Leathermarket JMB.

The KPIs shall be used as a basis for assessing potential improvements to the performance of the heat network installed at Meakin Estate.

The assessment is detailed in Section 5 and all KPIs are defined in Appendix 8 – KPI glossary.

4. Current performance summary

The site audits consisted of visiting the plantroom, three substations, a sample of the secondary network distribution pipework, and four dwellings across the site to account for variation in flats. The following flats were visited as part of the site audits:

- Flat 12, first floor, connected to substation 1
- Flat 30, ground floor, connected to substation 2
- Flat 110, ground floor, connected to substation 4
- Flat 112, first floor, connected to substation 4

For reference, the heat network is referred to using the following terminology in this report:

- Heat network systems:
  - Primary system – plant room and all pipework up to substations
  - Secondary system – communal pipework separated from the plant room by a substation
  - Tertiary system – pipework in dwellings delivering heating and hot water to residents
- Pipework sections:
  - Supply – from the plant room to the base of riser at each building.
  - Riser – vertical pipework between floors
  - Lateral – pipework in corridors from riser cupboards to dwelling entry
  - Terminal run – the final run of pipework serving only one dwelling

4.1. Overview of current performance

As part of the site audit process, issues have been identified that have a negative impact on the heat network. These have been evaluated against the risk parameters below:

- Thermal efficiency (e.g. impact to heat losses or heat generation efficiency)
- Operation expenditure (OPEX) (e.g. maintenance costs / electricity usage)
- Resident comfort (e.g. overheating, reliability of heat network, heating and hot water delivery times and temperatures)
- Risk to client (e.g. risk of system failure, regulatory risk)

To help determine the relative impact of each issue, the severity has been rated as one of the following against each of the above parameters:

- Major – The consequence of this issue produces a major impact on a specific risk parameter of the heat network
- Moderate – The consequence of this issue produces a moderate impact on a specific risk parameter of the heat network
- Minor – The consequence of this issue produces a minor impact on a specific risk parameter of the heat network

- Negligible – There is virtually no impact on the specific risk parameter of the heat network.

All issues identified and their severity ratings are detailed in Table 5 below.

It should be noted that potential design issues which could not feasibly be rectified at this stage (e.g. pipe sizing, equipment sizing, main plant equipment selection, network routing) have not been raised in the report.

Issues identified are compared to the minimum requirements in the CIBSE Heat Network Code of Practice (CP1) 2020. It is noted that this standard would not have been in place at the time of design and install of this heat network, so these comparisons should be considered as reference against current industry practice rather than evidence of a defect.

Item	Issue identified	Observation, root cause & impact	Thermal efficiency	OPEX	Resident comfort	Other
Dwelling – HIU & terminal run installation						
1	No HIUs and direct DHW system	No HIUs were installed throughout the development. Instead, DHW calorifiers were installed in the substations, which provided hot water to all dwellings. Space heating was delivered directly via the primary LTHW system to radiators within dwellings. Due to legionella control requirements (HSG 274 Pt 2), calorifiers are required to store hot water at 60°C, which increases the required flow temperature in the substations. These guidelines also require return temperatures of 50°C back to the calorifiers. Therefore, inclusion of calorifiers leads to elevated return temperatures and high heat losses, including high standing heat losses in the substations. The hot water system should be completely decommissioned, and individual heating and hot water systems (via HIUs) should be installed in each dwelling to limit losses.	Major	Major	Moderate	Negligible
2	Pipework completely uninsulated	The pipework within Flat 12 was completely uninsulated. This is causing high heat losses and is contributing to dwelling overheating. It is unclear if insulation was installed previously and removed during maintenance however, this is not currently in alignment with British Standard BS 5422 (2009 & 2023). Insulation should be upgraded to Heat network code of Practice (CP1 2020) guidance which specifies that 50 mm phenolic foam insulation should be installed on all primary and secondary pipework.	Major	Major	Moderate	Negligible

Item	Issue identified	Observation, root cause & impact	Thermal efficiency	OPEX	Resident comfort	Other
3	No heat metering of consumption within dwellings	No heat meters were seen within any of the visited dwellings. Without heat metering, heat supply to each dwelling cannot be measured, and data cannot be used for metering and billing (M&B) or performance monitoring purposes. Metering of heat supply within dwellings is a requirement of the Heat Metering & Billing Regulations 2014, and it should be ensured that dwellings are fitted with operational heat meters if alterations to dwelling heat supply is carried out.	Negligible	Minor	Negligible	Moderate
Dwelling – Standby & DHW performance						
4	Inaccessible DHW pipework and recirculation loops	The recirculation loops on the DHW systems within dwellings are located within the building fabric and are not accessible. Therefore, installation of temperature control valves (TCVs) to provide control would require significant disruption and fabric works. This significantly increases the complexity and cost of recommissioning works on the existing system.	Negligible	Negligible	Negligible	Minor
5	Low DHW final outlet temperatures	In Flat 30, the final outlet DHW temperature at the kitchen outlet was 46°C. This is lower than the required final outlet temperature of 60°C, as specified by HSG 274 legionella guidance, resulting in poor resident comfort and a risk of legionella exposure. There was no temperature mixing valve (TMV) present under the kitchen tap to explain the low temperature measurement. Therefore, due to the location of this dwelling towards the index point of the network, it is suspected that poor balancing and excessive heat losses are the causes. If a 4 pipe system is to be retained, recommissioning of the hot water recirculation system is required. However,	Negligible	Negligible	Major	Negligible

Item	Issue identified	Observation, root cause & impact	Thermal efficiency	OPEX	Resident comfort	Other
		installation and adequate commissioning of HIUs would enable all dwellings to receive DHW at 50°C and remove the flow balancing issues currently observed on site.				
6	Low kitchen tap DHW flow rates	Within Flats 12 and 30, DHW flow rates of 4 and 6 l/min were seen at the kitchen outlet respectively. Part G of Building Regulations indicate that a maximum flow rate of 8 l/min is recommended at sink taps. The recorded flow rates are much lower than this limit and at this stage, it is unclear if the hot water or mains cold water system is creating this problem. If a 4 pipe system is to be retained, an investigation of the cold water system should be undertaken for pressure issues and the hot water system should be investigated for balancing issues. However, if a 2-pipe system and HIUs are to be installed, it should be ensured that the cold water system is balanced and all HIUs receive adequate differential pressure.	Negligible	Negligible	Major	Negligible
Dwelling – Space heating performance						
8	No dwelling heating control	In Flat 30, the programmer was found to be broken and the actuator head on the space heating circuit had been removed. The residents are therefore controlling space heating using the thermostatic radiator valves (TRVs). Controlling space heating in this way elevates the risk of TRVs being exposed to pressures greater than their maximum pressure rating. This, in turn, provides a risk of radiators bypassing if/when TRVs fail and residents becoming unable to control their heating. Without adequate space heating control, elevated return temperatures and	Moderate	Moderate	Moderate	Negligible

Item	Issue identified	Observation, root cause & impact	Thermal efficiency	OPEX	Resident comfort	Other
		heat losses are experienced on the network and resident discomfort occurs, particularly in summer months. All faulty programmers and missing space heating actuators should be replaced to allow the residents to more adequately control their heating.				
9	Radiator sizing	The radiators installed in dwellings are sized to meet the heat load of the building at a c. 65/50°C temperature profile. This constrains the network flow temperature to a minimum of 65°C as any further reduction to the flow temperature will not provide enough heat output to meet the building heat losses. A higher flow temperature leads to increased gas consumption to provide the same heat output. If significant retrofit works are to take place, the radiators should be replaced and sized to accommodate the lowest possible flow temperature to reduce heat losses, gas consumption and increase decarbonisation feasibility (55°C).	Major	Major	Moderate	Negligible
Secondary network						
10	Plastic network pipework	Throughout the secondary network, plastic PVC-U pipework was seen on the DHW and space heating circuits. Extra expansion provision is required for plastic pipework compared to steel/copper pipework, due to the higher coefficient of expansion. Without this, there is a risk of pipework damage or failure. Plastic pipework also allows a higher rate of oxygen diffusion, leading to more active corrosion and a higher risk of corrosion damage and equipment failure.	Negligible	Moderate	Negligible	Major

Item	Issue identified	Observation, root cause & impact	Thermal efficiency	OPEX	Resident comfort	Other
		Any plastic pipework should be replaced with steel/copper to mitigate these risks and prevent premature pipe failure. Where plastic pipework cannot be removed, suitable expansion provision should be installed and the water quality should be well managed to limit corrosion as much as possible.				
11	Insulation thickness and material on network pipework does not meet industry recommendations	The secondary network pipework was insulated with 13-20 mm black nitrile rubber insulation. This is causing high network heat losses, contributing to a reduced network efficiency. With this insulation installed, heat losses from these sections of insulated pipework exceed those required by British Standard BS 5422 (2009 & 2023). Insulation should be upgraded to CP1 2020 guidance which specifies that 50 mm phenolic foam insulation should be installed on all primary and secondary pipework.	Major	Major	Moderate	Negligible
12	Inaccessible pipework	The majority of pipework on the secondary network is boxed in/located within the building fabric and so is not easily accessible. Therefore, modification to the existing pipework would require significant disruption and fabric works. This significantly increases the complexity and cost of retrofit works on the existing system. Retrofitted pipework should be located outside of the building fabric to enable access for maintenance, without requiring disruptive fabric works.	Negligible	Negligible	Negligible	Minor

Item	Issue identified	Observation, root cause & impact	Thermal efficiency	OPEX	Resident comfort	Other
13	Bypasses on DHW system in multiple locations	There were several recirculation loops on the DHW network within dwellings, outside dwellings and at the end of lateral runs, all of which were uncontrolled. This causes high flow rates of DHW to bypass through the system, leading to high return temperatures and heat losses. If a 4 pipe system is to be retained, recommissioning of the hot water recirculation system and installation of TCVs is required. However, it is recommended that installation and adequate commissioning of HIUs would enable DHW return temperatures to be much lower, limiting heat losses.	Major	Major	Moderate	Negligible
Substation						
14	Heat meters not functional	None of the heat meters seen in the substations were functioning correctly. Without operational heat meters, the heat supplied to each block cannot be measured. Additionally, heat meter data cannot be recorded for M&B purposes. Block-level metering of heat supply is a requirement of the Heat Metering & Billing Regulations 2014, therefore it should be ensured that substations are fitted with operational heat meters.	Negligible	Negligible	Negligible	Moderate
15	DHW 3-port valve actuators missing	Within each substation visited, the 3-port valve actuator on the primary side of the DHW plate heat exchanger (PHE) was missing. Without these valves in operation, there is a bypass on the primary side of the PHE, with no control of the flow temperature. This results in elevated return temperatures and high heat losses.	Major	Major	Negligible	Negligible

Item	Issue identified	Observation, root cause & impact	Thermal efficiency	OPEX	Resident comfort	Other
		If a 4 pipe system is to be retained, the 3-port valve should be reinstated and the actuator head replaced. However, it is recommended that the calorifiers are decommissioned and a 2-pipe network retrofitted.				
16	Hot water calorifiers storing water at unacceptable temperature	The DHW calorifier in substations 1 and 4 stored water at 55-56°C. In order to prevent legionella growth, hot water storage vessels are required to store hot water at 60°C, according to HSG 274 Part 2. Therefore, the calorifier does not comply with this requirement and currently presents a risk of legionella growth. This calorifier should have its set point increased to 60°C to minimise this risk and comply with the guidelines. Whilst on site, this issue was raised to Leathermarket JMB.	Minor	Moderate	Major	Moderate
17	Insulation thickness and material on network pipework does not meet industry recommendations	The substation pipework was insulated with 20-30 mm mineral wool insulation. There were also direct, uninsulated connections between pipework and pipework hangers, which act as thermal bridges for conductive heat loss. This is causing high network heat losses, contributing to a reduced network efficiency and overheating within substations. With this insulation installed, heat losses from these sections of insulated pipework exceed those required by British Standard BS 5422 (2009 & 2023). Insulation should be upgraded to CP1 2020 guidance which specifies that 50 mm phenolic foam insulation should be installed on all primary and secondary pipework.	Major	Major	Moderate	Negligible

Item	Issue identified	Observation, root cause & impact	Thermal efficiency	OPEX	Resident comfort	Other
18	Cylinder system with recirculation installed	Within each substation there was a single DHW calorifier, which provided hot water to each block. This also requires a recirculation system, with recirculation loops present on the primary network and within dwellings. Due to legionella control requirements (HSG 274 Pt 2), calorifiers are required to store hot water at 60°C, which increases the required flow temperature in the substations. These guidelines also require return temperatures of 50°C back to the calorifiers. Therefore, inclusion of calorifiers leads to elevated return temperatures and high heat losses, including standing heat losses in the substations. If a 4 pipe system is to be retained, recommissioning of the hot water recirculation system and installation of TCVs is required. However, it is recommended that the current DHW calorifiers and recirculation system are decommissioned. Instead, a 2-pipe system should be retrofitted to enable return temperatures to be much lower, limiting heat losses.	Major	Major	Moderate	Negligible
19	Oversized pipework	The pipework within all visited substations was generally oversized, with some pipework in substation 4 as large as DN100. Oversized pipework results in higher heat losses, contributing to a reduced network efficiency and overheating within the substations. Where pipework is due to be replaced or altered in the substations, more suitably sized pipework should be installed.	Moderate	Moderate	Negligible	Negligible
Primary network						

Item	Issue identified	Observation, root cause & impact	Thermal efficiency	OPEX	Resident comfort	Other
20	Unknown specification of underground pipework	Underground pipework has been installed on the primary network, connecting the plant room to the four substations. However, the specification of this pipework is unknown. This means that the pressure rating of the underground pipework cannot be confirmed. This presents a risk of pipework failure/damage if substations are to be removed and the pipework pressure rating is exceeded. The underground pipework specification and pressure rating should be confirmed prior to any substation removal works.	Negligible	Moderate	Negligible	Major
Energy centre						
21	Dosing pot bypass	A dosing pot is connected across the flow and return. When the connections are open, this creates a bypass leading to high return temperatures and heat losses; when isolated, a stagnant dead leg is created increasing the risk of bacterial growth and water quality issues. If a combined dosing pot and side stream filtration unit is installed around the pumps, a dosing pot will not be required. Consequently, the dosing pot should be isolated, drained, decommissioned and capped off.	Major	Moderate	Negligible	Negligible
22	Oversized boiler capacity	There are currently two boilers installed, each with a 1.34 MW burner, giving a total installed capacity of 2.68 MW. The estimated peak load of the site is c. 530 kW which is significantly smaller than the installed capacity. Having additional boilers is useful for redundancy but will increase maintenance cost, boiler cycling and controls complexity.	Moderate	Major	Negligible	Negligible

Item	Issue identified	Observation, root cause & impact	Thermal efficiency	OPEX	Resident comfort	Other
23	Unstable boiler flow temperature and sequencing	The flow temperature set points from the two boilers were 69°C and 72°C, with the boilers cycling every few minutes. The boilers should be operating to achieve identical temperatures in order to ensure a harmonious control strategy can be implemented. The variation in boiler set point is a consequence of poor boiler commissioning and leads to flow temperature instability. The boiler cycling is occurring every c.2 minutes, likely caused by their excessive size compared to network demand, and elevated network return temperatures. Frequent boiler cycling leads to increased gas consumption and wear and tear on the equipment, which could lead to downtime and unplanned maintenance requirements. This is also a risk to heat supply to the residents. The boilers should be recommissioned and the controls strategy updated to ensure a stable network flow temperature. If the boiler burners can be limited, this would help minimise cycling.	Moderate	Major	Moderate	Moderate
24	Oversized pumps at high speeds	The network distribution pumps were oversized and running at high speeds. The pumps were manually set to a differential pressure of 2 bar. This is increasing electricity consumption and caused by the significant number of network bypasses, which lead to continuous circulation of LTHW through the network. In turn, the pumps run with high set points and speeds to meet the required flow rates. Network bypasses should be recommissioned or removed where possible to reduce required network flow rates and thus pump set points. With this, the pump control strategy	Minor	Major	Negligible	Negligible

Item	Issue identified	Observation, root cause & impact	Thermal efficiency	OPEX	Resident comfort	Other
		should be also recommissioned to reduce electricity consumption.				
25	No network pump redundancy	1 of the 2 network pumps was electrically isolated, meaning there was no redundancy. If the operational network pump fails, it will lead to a disruption in heat supply to the residents. It is unclear if the pump was isolated due to pump failure, but the standby pump should be repaired and unisolated to ensure a reliable backup in case of failure.	Negligible	Negligible	Moderate	Negligible
26	Combined air & dirt separator and low loss header	Within the plant room, there was a combined air and dirt separator and low loss header. This means that there is no stratification within the low loss header, resulting in high boiler return temperatures and boiler cycling. The combined unit also produces a high pressure drop on the primary circuit, increasing the required boiler shunt pump speeds and thus electricity consumption. A separate air and dirt separator should be installed and the low loss header should be split, with a thermal store plumbed between flow and return. This will enable stratification and allow the boiler to operate for longer periods without cycling, whilst limiting pressure drop and required pump speeds. This will also reduce electricity consumption.	Moderate	Major	Negligible	Negligible
27	No quick fill loop on cold water connection	There was no quick fill loop installed on the cold water connection to the LTHW system. This means that, if the pressurisation unit is in fault or awaiting recommissioning, the system cannot be filled as required.	Negligible	Negligible	Negligible	Minor

Item	Issue identified	Observation, root cause & impact	Thermal efficiency	OPEX	Resident comfort	Other
		A quick fill loop should be installed, such that the system can be filled without requiring the pressurisation unit.				
28	1 boiler shunt pump operating when boiler not on	One of the boilers was inactive, but its shunt pump was still operating and so circulating colder water through the boiler circuit. This results in flow temperature dilution and lowers the primary network flow temperature, meaning the required boiler flow temperature must be elevated to meet the network requirements. This increases gas consumption. Also, as there is no shunt pump rotation, there is more wear and tear on the shunt pumps, which could lead to down time and unplanned maintenance requirements if they fail. The controls strategy should be updated to rotate the shunt pumps with the same schedule as for the boilers, such that when a boiler is disabled, its corresponding shunt pump is also disabled.	Moderate	Moderate	Negligible	Minor
29	Oversized expansion volume	Within the plant room, there were four 800L expansion vessels, providing a total expansion volume of 3200L for the primary circuit. This is much higher than what is required for a primary network of this size. This means at least one of the expansion vessels is redundant, resulting in additional maintenance responsibility and cost, as well as standing heat losses in the plant room.	Minor	Moderate	Negligible	Negligible
30	Insufficient insulation thickness, type and install	The plant room pipework was insulated with 20-50 mm mineral wool insulation. There were also direct, uninsulated connections between pipework and pipework hangers, which act as thermal bridges for conductive heat loss. This is causing high network heat losses, contributing to a	Major	Major	Moderate	Negligible

Item	Issue identified	Observation, root cause & impact	Thermal efficiency	OPEX	Resident comfort	Other
		reduced network efficiency and overheating within the plant room. Insulation should be upgraded to CP1 2020 guidance which specifies that 50 mm phenolic foam insulation should be installed on all primary and secondary pipework.				
31	No reverse return boiler arrangement	The boilers were arranged in a direct return arrangement. This means that, the boiler closest to the low loss header in the primary circuit is the first for boiler return LTHW to go through and the last for boiler flow LTHW to leave. This results in uneven flow distribution between the two boilers and a variation in boiler set point to achieve a uniform boiler flow temperature. The hydraulic layout should be altered to provide a reverse return boiler arrangement.	Minor	Negligible	Negligible	Minor
32	BMS not set up	The BMS was not set up correctly during the site audit with manual settings applied on several pieces of equipment (pumps, boilers, shunt pumps). However, the BMS panel indicated that all equipment was running in 'auto'. This means equipment is not being controlled in response to the system demand and is running at higher speeds and outputs than required. This leads to increased electricity and gas consumption. An in depth assessment of the BMS should be carried out to understand why equipment is not responding in line with the controls strategy. The BMS and equipment controls should be recommissioned to ensure that the controls strategy is correctly implemented.	Moderate	Major	Negligible	Negligible

Item	Issue identified	Observation, root cause & impact	Thermal efficiency	OPEX	Resident comfort	Other
33	Oversized pipework	The pipework within the plant room was generally oversized, with the majority of pipework sized to DN100. Oversized pipework results in higher heat losses, contributing to a reduced network efficiency and overheating within the substations. Where pipework is due to be replaced or altered in the plant room, more suitably sized pipework should be installed.	Negligible	Moderate	Negligible	Major

Table 5: Plant room, network and dwelling issues and severity ratings

4.1.1. Standby performance

The system is designed to operate with a constant flowrate both on the space heating circuit and on the DHW circuit - there a bypass valves installed on both circuits. As such, there is no requirement for standby or keep-warm since heat is always circulating.

As there is no heat metering within dwellings, this operation could not be quantified during the site audits but it is expected to be similar to that outlined in the below sections for DHW and space heating operation.

4.1.2. DHW performance

The results of DHW testing within 2 of the four dwellings visited during the site audit are detailed below in Table 6. The lack of dwelling heat metering meant that primary temperature, flow and power readings could not be obtained.

Dwelling	Flat 12	Flat 30
Time to deliver 45°C to the kitchen tap (s)	20	25
Kitchen tap flow rate (l/min)	4	6
DHW outlet temperature at 60 seconds (°C)	56	46
DHW final outlet temperature (°C)	56	46

Table 6: Observations made during stable DHW operation.

4.1.2.1. DHW flow temperature requirements

Due to legionella control requirements (HSG 274 Pt 2), calorifiers must be maintained at a minimum temperature of 60°C and outlets without TMVs installed must achieve 50°C within 60 seconds of initial draw off.

The inclusion of hot water cylinders and PHEs in the substations means the boilers must provide at least 65°C to the calorifiers to enable hot water generation to suitable temperatures. Despite the boilers generating at c. 70-75°C, the calorifiers were storing water at c. 56-60°C and consequently, the requirements of HSG 274 Pt 2 are not met for all calorifiers and therefore the DHW temperatures observed in dwellings were not meeting the required temperatures.

A number of factors could also be exacerbating this issue. Given the proximity to their respective substations, it is likely that heat losses and flow starvation, generated by other bypasses between the substation and the dwelling, are preventing even distribution of flow to each resident. Variable DHW temperatures across the development are likely to be prevalent, increasing resident discomfort particularly within flats furthest from the substations.

The existing network should either be recommissioned to ensure even distribution of flow to each property and calorifier temperatures reviewed. Or alternatively, removing the DHW calorifiers and installing instantaneous HIUs in each dwelling will enable a reduction in DHW set point to 50°C and a reduction in legionella risk as stored water volume is significantly reduced (HIUs are considered a small enough volume to be “low risk” under HSG 274).

4.1.3. Space heating performance

The space heating circuit is fed directly from the primary LTHW circuit which feeds radiators within the dwellings and the community centre. The delivery of space heating was tested at the radiators within Flat 12. The observations are detailed in Table 7. It should be noted that the resident in flat 30 did not want their heating switched on during the visit.

Due to the lack of heat metering available on site, no meter readings could be obtained, therefore tertiary radiator temperatures were measured on the radiator flow and return pipework. Given that there is no available common flow and return, the temperatures could only be recorded local to each radiator.

Radiator location	Space heating flow temperature (°C)	Space heating return temperature (°C)	Temperature differential (°C)
Kitchen	65	55	10
Living room	63	48	15
Hallway	65	60	5
Bathroom	64	64	0

Table 7: Tertiary space heating temperature measurements during space heating operation in Flat 12.

A detailed assessment of radiator sizing and operating temperatures indicates that the radiators are sized to achieve the heat loads in each room at a temperature profile of 65/50°C. Whilst the design information was not provided to confirm this, it is expected that this was the original design criteria. Further information on this analysis is provided in Appendix 6 - Space heating temperature calculation methodology.

4.1.3.1. Variable radiator return temperatures

The radiator circuits within dwellings are poorly balanced and this is creating variable heat delivery between rooms. Underheating and overheating of rooms is likely to be a consistent issue throughout the development. This is shown in Table 7, where these temperature differentials varied from 0°C for the bathroom radiator to 15 °C for the living room radiator.

This is an indicator that radiators have not been suitably balanced to minimise return temperatures and ensure even heat distribution across all radiators. Other radiators not tested may have exhibited even smaller temperature differentials, indicating that bypasses may be occurring across several areas of the space heating network. As a result of this, the heat losses will be elevated and the likelihood of residents experiencing poor heat supply in individual rooms is also increased.

Pressure independent TRVs should be installed on all radiators within dwellings to ensure even heat distribution is achieved.

4.1.3.2. Lack of space heating control

Broken heating programmers were found in Flats 30 and 12. A missing actuator head was also observed on the space heating circuit also in Flat 30. TRV heads had been removed Flat 12, creating an inability for the resident to isolate the individual radiator.

Without suitable heating control, radiators will bypass, resulting in elevated return temperatures and heat losses across the space heating network. Additionally, uncontrolled heating causes dwelling overheating, especially during summer periods, which significantly worsens resident comfort.

Where there are faulty programmers, missing space heating actuators or missing TRV heads, these should be replaced to enable sufficient dwelling space heating control, leading to improvements in resident comfort and network heat losses.

4.2. Risks with current operation

The concerns with the current operation are highlighted in the sections above.

To summarise, the risks associated with the continued running of the scheme in its current state are as follows:

Item	Risk	Item	Risk
Ability to decarbonise	High	Operating pressures	Low
Access for maintenance and replacement	High	Resident comfort	High
Data capture and visibility	High	Scalding	Medium
Electricity consumption	High	Security of heat supply	Medium
Heat losses	High	System lifespan	High

Table 8: Summary of risks with current operation

5. Optimisation Opportunities

There are currently several key issues impacting the performance of the Meakin Estate heat network:

- The heat loss across the system is higher than would be expected from a well performing network, which is due to the 4-pipe, constant flow network arrangement.
- Fixed space heating and DHW bypasses are present across the network, with poor network insulation of low thicknesses, as well as bypassing radiators with limited space heating control. These issues contribute to significant heat losses and increased return temperatures. Plastic secondary network pipework also presents several risks to system integrity.
- The installation of DHW calorifiers and PHEs within substations are also constraining both the flow and return temperatures to greater than what is achievable for instantaneous DHW production.
- In the energy centre, oversized and poorly controlled equipment and pipework, as well as several hydraulic issues, lead to increased equipment wear, maintenance responsibility, and further heat losses.

The proposed options for performance improvements have been grouped into two proposed packages of works, which can be summarised as follows:

- Work Package 1 proposes to reduce return temperatures and heat losses across the network through recommissioning dwelling radiators, installing temperature control valves (TCVs) on the DHW network to achieve the temperatures required by HSG274 and minimise bypass flow rate where possible. Reinsulating all accessible pipework will also take place. In the plant room and substations, the BMS will be reinstated and recommissioning works are proposed for the boilers, pumps and DHW calorifiers. This will minimise outages, reduce heat losses, flow temperatures, gas and electricity consumption.
- Work Package 2 proposes to carry out a 4-pipe to 2-pipe network conversion, substantially reducing heat losses and return temperatures further. This includes the decommissioning of the DHW calorifiers and space heating network, whilst retaining the DHW pipework as the 2 pipework system. Installation of single-plate HIUs, PI-TRVs and heating thermostats/programmers in dwellings and the community centre will provide the alternative method of generating heating and hot water to residents. Additional hydraulic works will be undertaken in the plant room, along with the replacement of the network pumps, decommissioning of the dosing pot and installation of a side stream filtration unit. Boiler and pump recommissioning is also proposed, as in Work Package 1. Again, this will reduce flow temperatures, gas and electricity consumption and also minimise network heat losses and maintenance responsibility.
- Work Package 3 proposes to incorporate all of Work Package 2, with additional decommissioning of substation PHEs and replacement of dwelling/communal radiators, central boilers and secondary network pipework. Major replumbing works are also proposed within the energy centre, including the removal of the low loss header and installation of thermal stores and a network 3-port valve. This will further limit flow and return temperatures and heat losses, whilst improving boiler generation efficiency and flow temperature stability.

Issues have also been identified at Meakin Estate regarding water quality and other risks that should be addressed to mitigate the impact on system reliability and equipment lifespan. These items are not always related to a direct reduction in operating costs so are presented in Section 6.1 separately to the optimisation opportunities financial analysis in Section 6.2.

5.1. Work Packages

5.1.1. Work Package 1

Table 9 below details the interventions required to meet the aims of Work Package 1. Detail has been provided on the impact and influence on the KPIs.

#	Intervention	Additional detail and impact	KPIs influenced
Dwelling			
1	Recommission/balance radiator circuit	The current radiators within dwellings were providing uneven heat distribution across the dwelling. The radiators shall be balanced to ensure consistent heat outputs across all heating circuits. This will enable a reduction in overall primary return temperatures and network heat losses.	Average return temperature Heat network loss
2	Close and remove space heating bypasses within dwellings	Removing space heating bypasses within dwellings will reduce bypass flow rates, decrease the return temperature and space heating network flow rate.	Heat network losses Average return temperature Bypass flow rate
3	Insulate terminal pipework	All terminal pipework will be insulated with 50 mm phenolic insulation where possible to help reduce dwelling heat losses. Where there are spatial constraints that will prevent this, phenolic insulation of at least 25 mm will be installed.	Heat network loss
Network			
8	Close and remove network bypasses (excluding index dwellings)	Removing fixed bypasses on the DHW and space heating network will reduce bypass flow rates, decrease the return temperature and space heating network flow rate. This will not be performed for the recirculation loops on the DHW system as this is a requirement for Legionella compliance.	Heat network losses Average return temperature Bypass flow rate

#	Intervention	Additional detail and impact	KPIs influenced
9	Install/recommission TCVs on DHW recirculation loops	Temperature control valves (TCVs) on DHW recirculation loops will be recommissioned to provide an appropriate flow of DHW to keep the pipework warm, without causing unnecessarily high flow rates and uncontrolled network bypasses. Where these are not already present, or where current valves are confirmed to be faulty, new valves will be installed to prevent bypasses within the DHW circuit and promote even flow distribution. It should be noted these recirculation loops are located within building fabric, internal to the dwellings. As such, invasive fabric works may be required to locate them.	Heat network losses Average return temperature Bypass flow rate
10	Reinsulate network pipework	Changing insulation from 15-25 mm nitrile rubber/mineral wool to 50 mm phenolic insulation where possible on all risers and laterals will help reduce network heat losses. Where there are spatial constraints that will prevent this, phenolic insulation should be reduced to the maximum thickness allowed within the constrained area.	Heat network losses
Substation			
13	Recommission DHW 3-port control valves	Actuator heads were not present on the DHW 3-port valves, leading to no control on the secondary side of the substation PHEs. The actuator heads for the 3-port valves will be installed and have their set points and control operation reviewed to control and stabilise secondary flow temperatures.	Bypass flow rate Time below minimum flow temperature Flow temperature stability
14	Recommission DHW calorifier set point to 60°C	Hot water was provided to dwellings via DHW calorifiers in the substations, which were operating at ~56-60°C. The set points of any calorifiers below 60°C will be increased to 60°C in line with HSG 274. This will minimise legionella risk.	Maintenance frequency Major outages

#	Intervention	Additional detail and impact	KPIs influenced
15	Reinsulate substation pipework	Changing insulation from 20-50 mm mineral wool to 50 mm phenolic insulation where possible on all substation pipework will help reduce network heat losses.	Heat network losses
Energy centre			
18	Reinsulate plant room pipework	Changing insulation from 20-50 mm mineral wool to 50 mm phenolic insulation where possible on all plant room pipework will help reduce network heat losses.	Heat network losses
19	Reinstate BMS and controls strategy	The BMS control strategy will be reinstated to enable boilers and pumps to be controlled automatically in response to demand, rather than 'in hand', where the equipment is running at higher speeds and outputs than is necessary. This will reduce equipment wear, whilst lowering gas and electricity consumption and ensuring stable flow temperatures.	Maintenance frequency Flow temperature stability Carbon intensity of heat delivered
20	Recommission network and shunt pumps	The network and boiler shunt pumps were observed to be operating 'in hand', running at higher speeds than necessary. Recommissioning the pump set points and speeds will help to reduce electricity consumption of each pump.	Electricity consumption Carbon intensity of heat delivered
24	Recommission boiler set point to 70°C	The current boiler operating temperature is 69-72 °C. Temperatures can be altered to 70 °C and still provide sufficient heat loads to meet resident DHW and heating demands.	Average flow temperature Heat network losses

Table 9: Details and impacts of interventions suggested for Work Package 1

5.1.2. Work Package 2

Table 9 below details the interventions required to meet the aims of Work Package 2. Detail has been provided on the impact and influence on the KPIs.

#	Intervention	Additional detail and impact	KPIs influenced
Dwelling			
3	Insulate terminal pipework	All terminal pipework will be insulated with 50 mm phenolic insulation where possible to help reduce dwelling heat losses. Where there are spatial constraints that will prevent this, phenolic insulation shall be installed to the maximum possible thickness.	Heat network loss
4	Install pressure independent (PI-TRVs) on all radiators	Radiators within all dwellings and the community centre will have PI-TRVs installed to ensure consistent heating balancing and prevent space heating bypassing. This will avoid high heating return temperatures and reduce primary return temperatures.	Average return temperature Heat network losses
5	Replace heating thermostats/programmers	Heating thermostats and programmers will be replaced in dwellings to enable residents to control their heating, without relying solely on TRVs which is currently the case in some properties. This also remove the bypassing effect of the existing radiators.	Average return temperature Heat network loss
6	Install single-plate HIUs (with AMR metering)	Installing single-plate HIUs within dwellings will ensure instantaneous DHW delivery and improved space heating control, causing significant reductions in network return temperatures, leading to reduced heat losses. Also, the installation of HIUs with AMR metering will enable heat meter data to be recorded for metering and billing, as well as providing remote data access for performance monitoring purposes. Installation of HIUs will generate a much more reliable hot water supply to residents and, with correct commissioning, assist with the suspected flow starvation issues observed on the network currently.	Average return temperature Heat network loss
Network			

#	Intervention	Additional detail and impact	KPIs influenced
10	Reinsulate network pipework	Changing insulation from 15-25 mm nitrile rubber/mineral wool to 50 mm phenolic insulation where possible on all risers and laterals will help reduce network heat losses. Where there are spatial constraints that will prevent this, phenolic insulation of at least 30 mm will be installed.	Heat network losses
11	Decommission space heating pipework and repurpose DHW pipework for 2-pipe system	Decommissioning the space heating network pipework will allow conversion from a 4-pipe to a 2-pipe system, leading to a decrease in network length and thus heat losses. An expansion specialist will need to be consulted to investigate whether additional expansion provision is required for the secondary network, given that plastic pipework will be retained.	Maintenance frequency Major outages Heat network loss
Substation			
15	Reinsulate substation pipework	Changing insulation from 20-50 mm mineral wool to 50 mm phenolic insulation where possible on all substation pipework will help reduce network heat losses.	Heat network losses
16	Decommission DHW calorifiers and replumb LTHW pipework	As the system is being converted into a 2-pipe system, DHW calorifiers are not required.	Average flow temperature Heat network loss
Plant room			
18	Reinsulate plant room pipework	Changing insulation from 20-50 mm mineral wool to 50 mm phenolic insulation where possible on all plant room pipework will help reduce network heat losses.	Heat network losses
19	Implement the BMS and controls strategy	The BMS control strategy will be reinstated to enable boilers and pumps to be controlled automatically in response to demand, rather than 'in hand', where the equipment is running at higher speeds and outputs than is necessary. This will reduce equipment wear, whilst lowering gas and electricity consumption and ensuring stable flow temperatures.	Maintenance frequency Flow temperature stability Carbon intensity of heat delivered

#	Intervention	Additional detail and impact	KPIs influenced
20	Recommission network and shunt pumps	The network and boiler shunt pumps were observed to be operating 'in hand', running at higher speeds than necessary. Recommissioning the pump set points and speeds will help to reduce the flow rate and electricity consumption of each pump.	Electricity consumption Carbon intensity of heat delivered
21	Replace network pumps	The current network pumps are considerably oversized and running at high speeds. Installation of HIUs will significantly reduce flow rate requirements across the network, therefore smaller pumps can be retrofitted to align to these new requirements, minimising electricity consumption.	Electricity consumption Carbon intensity of heat delivered
22	Replace dosing pot with side-stream filtration unit	A combined side stream filtration unit and dosing pot shall be installed around the secondary pumps to provide minimum turndown protection on the pumps and enable the system to be filtered and dosed simultaneously. The removal of the existing dosing pot will prevent the formation of dead legs (mitigating the risk of poor water quality) and reduce	Bypass flow rate Heat losses
23	Replumb boilers to reverse return arrangement	The boiler hydraulic layout will be replumbed to provide a reverse return arrangement. This will prevent an uneven flow distribution between the two boilers and a variation in boiler set point to achieve a uniform boiler flow temperature.	Flow temperature stability
24	Recommission boiler set point to 70°C	The current boilers are cycling and operating temperature is 69-75 °C. Temperatures can be reduced to 70 °C and still provide sufficient heat loads to meet resident DHW and heating demands.	Average flow temperature Heat network losses

Table 10: Details and impacts of interventions suggested for Work Package 2

5.1.3. Work Package 3

Table 9 below details the interventions required to meet the aims of Work Package 3. Detail has been provided on the impact and influence on the KPIs.

#	Intervention	Additional detail and impact	KPIs influenced
Dwelling			
3	Insulate terminal pipework	All terminal pipework will be insulated with 50 mm phenolic insulation where possible to help reduce dwelling heat losses. Where there are spatial constraints that will prevent this, phenolic insulation shall be installed to the maximum possible thickness.	Heat network loss
4	Install PI-TRVs on all radiators	Radiators within all dwellings and the community centre will have PI-TRVs installed to ensure consistent heating balancing and prevent space heating bypassing. This will avoid high heating return temperatures and reduce primary return temperatures.	Average return temperature Heat network losses
5	Replace heating thermostats/programmers	Heating thermostats and programmers will be replaced in dwellings to enable residents to control their heating, without relying solely on TRVs. This will enable improved space heating control and remove the bypassing effect of the existing radiators.	Average return temperature Heat network loss
6	Install single-plate HIUs (with AMR metering)	Installing single-plate HIUs within dwellings will ensure instantaneous DHW delivery and improved space heating control, causing significant reductions in network return temperatures, leading to reduced heat losses. Also, the installation of HIUs with AMR metering will enable heat meter data to be recorded for metering and billing, as well as providing remote data access for performance monitoring purposes.	Average return temperature Heat network loss
7	Replace radiators	Radiators capable of meeting the room heating demand at a network flow temperature of 55°C will be installed in place of the current radiators. This enables a reduction in network flow temperature via boiler recommissioning in the plant room and consequently heat losses.	Heat network losses Average flow temperature
Network			
10	Reinsulate network pipework	Changing insulation from 15-25 mm nitrile rubber/mineral wool to 50 mm phenolic insulation where possible on all risers and laterals will help reduce network heat losses. Where there are spatial constraints	Heat network losses

#	Intervention	Additional detail and impact	KPIs influenced
		that will prevent this, phenolic insulation of at least 30 mm will be installed.	
11	Decommission all secondary network pipework and retrofit new 2-pipe heat network	Decommissioning the existing secondary network pipework will eliminate the risks with operating with plastic pipework and allow conversion from a 4-pipe to a 2-pipe system, leading to a decrease in network length and thus heat losses. New steel pipework will be installed alongside the existing DHW pipework, with the existing DHW pipework decommissioned after completion. Given this may require invasive fabric works to access risers and some lateral pipework, this phased approach will minimise downtime for residents.	Maintenance frequency Major outages Heat network loss
Substation			
15	Reinsulate substation pipework	Changing insulation from 20-50 mm mineral wool to 50 mm phenolic insulation where possible on all substation pipework will help reduce network heat losses.	Heat network losses
16	Decommission DHW calorifiers and replumb LTHW pipework	Removing the DHW calorifiers and pipework within the substations as both will not be required with the new 2 pipe heating system.	Average flow temperature Heat network loss
17	Remove substations (PHEs)	Currently, the PHE in each substation provides a hydraulic break between the primary (buried) network and the secondary DHW network. These PHEs will be removed and primary LTHW pipework replumbed into the secondary side, without hydraulic separation. This will enable a reduction in boiler/network flow temperatures, whilst still meeting sufficient heat loads for tertiary DHW and heating demands.	Average flow temperature Heat network losses
Energy centre			
18	Reinsulate plant room pipework	Changing insulation from 20-50 mm mineral wool to 50 mm phenolic insulation where possible on all plant room pipework will help reduce network heat losses.	Heat network losses

#	Intervention	Additional detail and impact	KPIs influenced
19	Implement new BMS controls strategy	The BMS control strategy will be reinstated to enable boilers and pumps to be controlled automatically in response to demand, rather than 'in hand', where the equipment is running at higher speeds and outputs than is necessary. This will reduce equipment wear, whilst lowering gas and electricity consumption and ensuring stable flow temperatures.	Maintenance frequency Flow temperature stability Carbon intensity of heat delivered
21	Replace and network pumps	The current network pumps are considerably oversized and running at high speeds. Installation of HIUs will significantly reduce flow rate requirements across the network, therefore smaller pumps can be retrofitted to align to these new requirements, minimising electricity consumption.	Electricity consumption Carbon intensity of heat delivered
20	Commission network and shunt pumps	New shunt pumps and network pumps will require commissioning.	Electricity consumption Carbon intensity of heat delivered
22	Replace dosing pot with side-stream filtration unit	A combined side stream filtration unit and dosing pot shall be installed around the secondary pumps to provide minimum turndown protection on the pumps and enable the system to be filtered and dosed simultaneously. The removal of the existing dosing pot will prevent the formation of dead legs (mitigating the risk of poor water quality) and reduce	Bypass flow rate
23	Replumb boilers to reverse return arrangement	The boiler hydraulic layout will be replumbed to provide a reverse return arrangement. This will prevent an uneven flow distribution between the two boilers and a variation in boiler set point to achieve a uniform boiler flow temperature.	Flow temperature stability
25	Reduce network flow temperature to 55°C	The current boiler operating temperature is 70-75 °C. With the removal of the substation PHEs and radiator replacement, network flow temperatures can be reduced to 55°C and still provide sufficient heat loads to meet resident DHW and heating demands. Boilers are to operate 60 °C	Average flow temperature Heat network losses

#	Intervention	Additional detail and impact	KPIs influenced
20	Replace boilers and shunt pumps	The site peak load is estimated to be c. 530 kW, however 2680 kW of boiler capacity is installed. The current boilers will be replaced with more appropriately sized units and commissioned with an improved control strategy. This will improve heat generation efficiency and maintenance responsibility, as well as enabling the boiler set point reduction and subsequently the network flow temperature to be reduced to 55 °C, reducing gas consumption.	Average flow temperature Heat generation efficiency Maintenance frequency Carbon intensity of heat delivered
27	Install network 3-port valve	A network 3-port valve will help to stabilise flow temperatures to the network and ensure consistent heat delivery to dwellings.	Flow temperature stability Time below minimum flow temperature
28	Split low loss header, install buffer vessel and replumb plant room pipework	Removing the low loss header and replacing with thermal storage will improve flow temperature stability and significantly reduce return temperatures to the boilers. This will consequently increase the likelihood of the boilers condensing, improving generation efficiency.	Average return temperature Heat generation efficiency Heat network loss

Table 11: Details and impacts of interventions suggested for Work Package 3

5.2. Summary of performance improvement options

The performance improvement measures are summarised below in Table 12.

#	Intervention	WP1	WP2	WP3
Dwelling				
1	Recommission/balance radiator circuit	X		
2	Close and remove space heating bypasses within dwellings	X		
3	Insulate terminal pipework	X	X	X
4	Install PI-TRVs on all radiators		X	X
5	Replace heating thermostats/programmers		X	X
6	Install single-plate HIUs (with AMR metering)		X	X
7	Replace radiators			X
Network				
8	Close and remove network bypasses (excluding index dwellings)	X		
9	Install/recommission TCVs on DHW recirculation loops	X		
10	Reinsulate network pipework	X	X	X
11	Decommission space heating pipework and repurpose DHW pipework for 2-pipe system		X	
12	Decommission all secondary network pipework and retrofit new combined pipework			X
Substation				
13	Recommission DHW 3-port control valve	X		
14	Recommission DHW calorifier set point to 60°C	X		
15	Reinsulate substation pipework	X	X	X
16	Decommission DHW calorifiers and replumb LTHW pipework		X	X
17	Remove substations (PHEs)			X
Energy centre				
18	Reinsulate plant room pipework	X	X	X
19	Reinstate BMS and controls strategy	X	X	X
20	Recommission network and shunt pumps	X	X	X
21	Replace network pumps		X	X
22	Replace dosing pot with side-stream filtration unit		X	X
23	Replumb boilers to reverse return arrangement		X	X

#	Intervention	WP1	WP2	WP3
24	Recommission boiler set point to 70 °C	X	X	
25	Reduce network flow temperature to 55°C			X
26	Replace boilers and shunt pumps			X
27	Install network 3-port valve			X
28	Split low loss header, install buffer vessel and replumb pipework			X

Table 12: Summary of recommendations

5.3. Performance impact

5.3.1. KPIs & data availability

Table 13 features a full set of KPIs which FairHeat have developed to assess the overall performance and reliability of a heat network, the calculated baseline value for Meakin Estate and the impact of each work package on the KPIs.

The information provided in order to support calculation of KPIs is detailed in Appendix 9 – RFI list. However, certain KPIs in Table 13 could not be estimated due to a lack of available data.

Type	Area	KPI / metric	Base Case	WP1	WP2	WP3	Unit
Performance	Energy Centre	Heat generation efficiency	80	80	80	90	%
		Average flow temperature	71	70	70	55	°C
		Average return temperature	63	60	60	40	°C
	Heat network	Heat network loss	1003	604	276	221	W/ dwelling
		Bypass flow rate	Data unavailable				%
		Average flow temperature	56[1] 54[2]	60[1] 65[2]	60	52	°C
		Average return temperature	52[1] 50[2]	50	50	38	°C
	Dwelling	Average VWART across all	51	50	40	36	°C

Type	Area	KPI / metric	Base Case	WP1	WP2	WP3	Unit
		modes of operation					
Reliability	Energy Centre	Time below minimum flow temperature	Data unavailable				hours/ year
		Flow temperature stability	Data unavailable				% time
		Major outages (per 100 days, over 4 hours, non-PPM)	0.30	0.26	0.12	0.02	No.
		Plant room VWAFT	Data unavailable				°C
	Dwelling	Reported interruptions and reductions (per 100 dwellings per 3 month period)	8.8	7.5	3.5	0.4	No.
		Maintenance frequency (per 100 dwellings per 3 month period)	8.8	7.5	3.5	0.4	No.
Financial	Resident	Year 1 required heat tariff	27.53	20.84	20.32	16.38	p/kWh
Carbon	All	Carbon intensity of heat delivered	0.683	0.514	0.501	0.403	kg CO_2 / kWh

Table 13: KPIs for the current performance compared to the expected performance after optimising according to each Work Package. [1]Average network temperatures for DHW circuit pipework. [2]Average network temperatures for space heating circuit pipework

5.3.2. Heat losses

A heat loss model has been produced based on the installation observed during the site visit. All assumptions are detailed in Section 14.2.

The heat loss model calculated that the current heat loss across the scheme is c. 1,059,700 kWh/year, 8,787 kWh/dwelling/year or 1,003 W/dwelling.

Actual gas consumption data has been used to validate these heat losses since residential consumption data was not available. Typically, a total average demand of 2,920 kWh/dwelling/year is assumed based on the BESA UK HIU Test Regime. However, a dwelling heat consumption of 6,000-13,600 kWh/dwelling/year has been assumed. This is based on typical dwelling gas usage from Ofgem and assumes a gas boiler efficiency of 80%. Given the age and condition of the Meakin Estate heat network compared to a typical New Build heat network development, assuming new building heating usage would be ineffective and skew results. Using this assumption, analysis results in an estimated annual heat loss of c. 1,275,600 kWh/year, 10,371 kWh/dwelling/year or 1,184 W/dwelling. This suggests that assumptions and decisions used in the model are well matched with actual performance.

The discrepancy between the modelled base case heat loss and the gas data is due to the differences in installation on site. As FairHeat only accessed a small sample of dwellings (4 of 123), assumptions have been made about the performance of the remaining dwellings which could have been marginally worse than the performance witnessed by FairHeat on site. Additionally, gas data was received from April 2023 to March 2024, which may not be representative of the true values that are currently reflecting the performance observed onsite. As the heat losses are within 15% of gas data, this is a reliable approximation to heat loss.

Heat loss model outputs for the base case and each work package are show in Table 14 and displayed visually in the figures below.

Heat losses	Gas Data	Base Case	WP1	WP2	WP3
Total (W/dwelling)	1,184	1,003	604	276	221
Total (kWh/dwelling/yr)	10,371	8,787	5,289	2,422	1,934
Total (kWh/yr)	1,275,606	1,080,763	650,589	297,914	237,903
Reduction compared to Base Case	-	-	40%	72%	78%
Figure reference	-	Figure 6	Figure 7	Figure 8	Figure 9

Table 14: Heat loss model outputs for the Base Case and all Work Packages

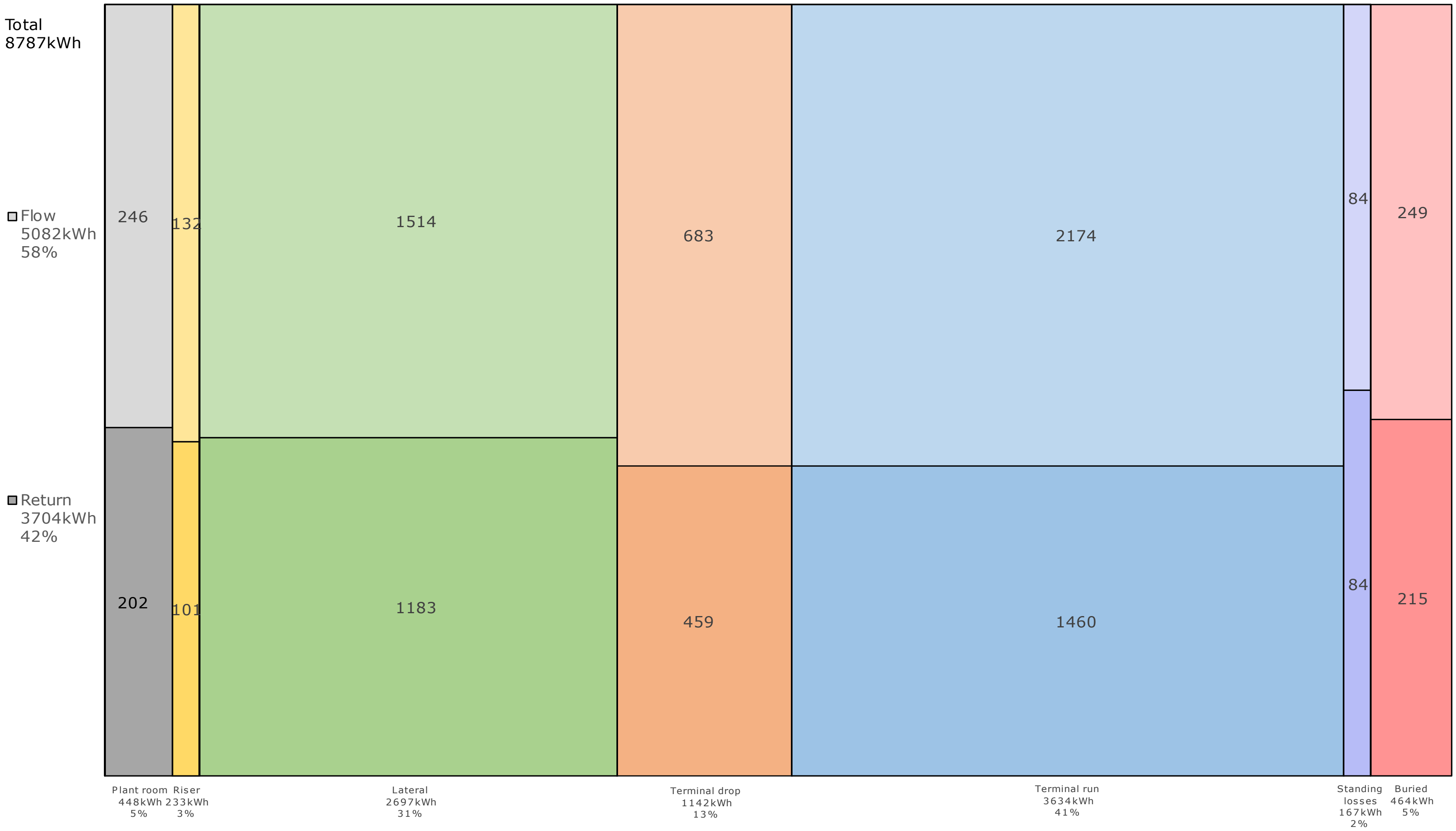

Figure 6: The results of a heat loss model detailing the current kWh heat losses per resident per annum broken down into pipework sections for both flow and return pipework

Figure 7: The results of a heat loss model detailing the Work Package 1 kWh heat losses per resident per annum broken down into pipework sections and flow and return pipework

Figure 8: The results of a heat loss model detailing the Work Package 2 kWh heat losses per resident per annum broken down into pipework sections and flow and return pipework. Standing losses increase in Work Package 2 due to HIU installation, however there are minor reductions due to removal of the DHW calorifiers.

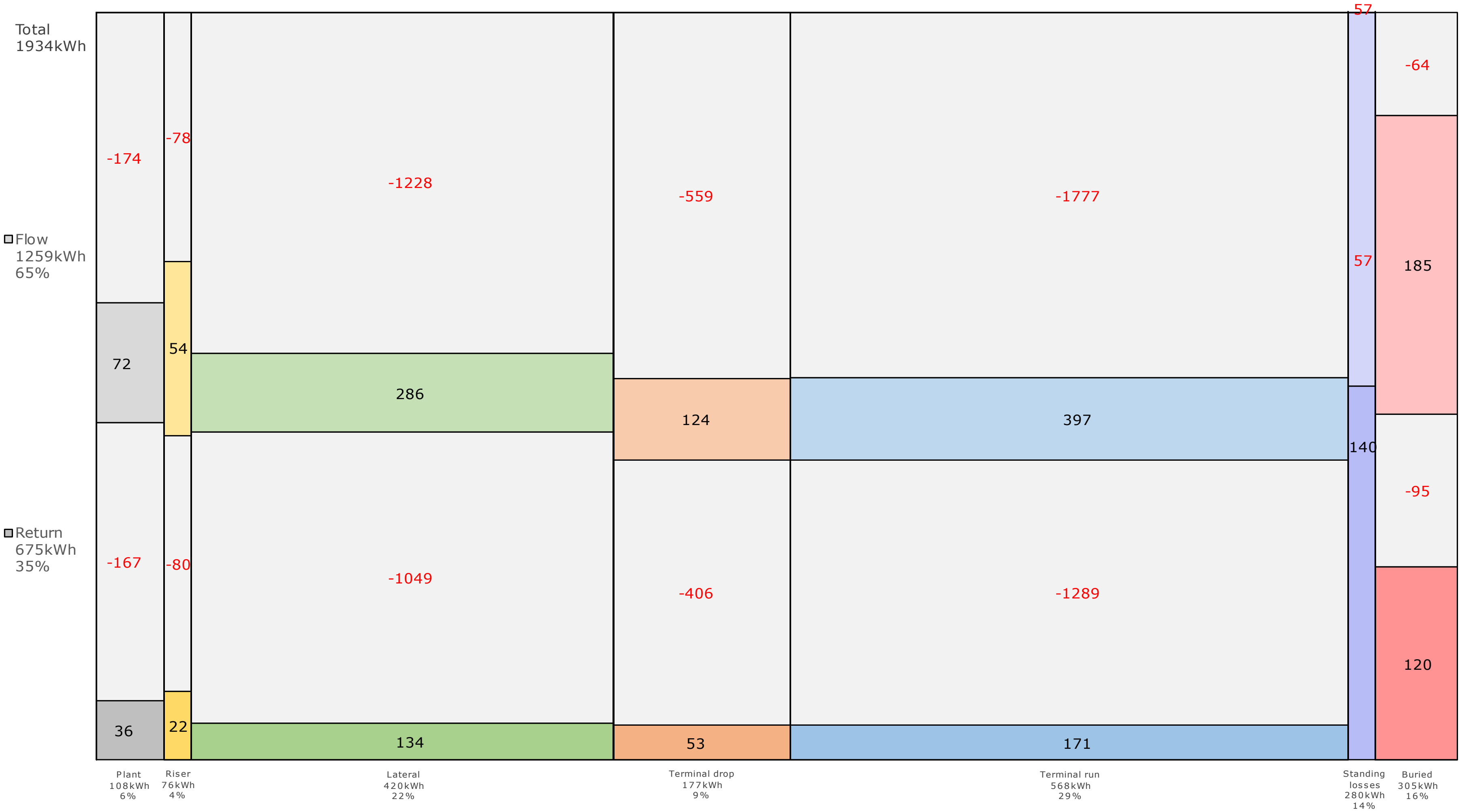

Figure 9: The results of a heat loss model detailing the Work Package 3 kWh heat losses per resident per annum broken down into pipework sections and flow and return pipework. Standing losses increase in Work Package 3 due to HIU installation, however there are minor reductions due to removal of the DHW calorifiers and PHEs.

5.4. Potential for future decarbonisation

Heat networks are not currently taxed on their operational carbon emissions. However, legislation was passed in 2019 which requires the UK greenhouse gas emissions to be brought down to net zero by 2050, meaning that more financial and regulatory frameworks will likely be put in place to push operational heat networks to decarbonise.

To decarbonise, it is likely that heat networks will need to use heat pumps or connect to a district heat network to generate heat. Both approaches operate more efficiently at lower output temperatures (most district heat networks will also use heat pumps), so reducing operating temperatures now should be considered to futureproof the system for low carbon generation technology.

From a perspective of preparing the system for a future heat pump installation, a maximum 65 °C sitewide flow temperature is required to operate within acceptable air source heat pump efficiency ranges. Table 15 summarises the future proofing enabled by each work package.

	WP1	WP2	WP3
Can ASHPs be retrofitted?	No	Yes	Yes
Are temperatures suitable for heat pump?	No	Yes – given top-up boilers are also used during peak demand periods	Yes
CAPEX & Complexity considerations	Low loss header would require replacement for thermal store and PHEs would require removal to facilitate ASHP operation (due to space heating temperature requirements)		-
Additional OPEX considerations	Much higher temperatures during increased demand would impact SCOP vs WP2 & WP3	Higher temperatures during increased demand would impact SCOP vs WP3	-
Overall suitability	No – ASHP operation would be infeasible, complex and very expensive to run at high temperatures	Yes – but would be more expensive and complex, as well as require boiler top-up at peak demand	Yes

Table 15: Table summarising the suitability of each work package for installing a heat pump

6. Techno-economic assessment

The interventions proposed in the work packages in Section 5 include only items of work that result in a performance improvement that can be modelled against the current system performance.

Further interventions have been identified that are expected to have a significant benefit to system reliability and lifespan, despite not having a direct impact of performance. These items of works are presented in the section below and it is strongly recommended these are carried out (unless highlighted otherwise). The modelled impact of each of the work packages presented in Section 6.2 assumes that all recommended risk mitigation works in Section 6.1 are implemented.

All costs at this stage are estimated based on previous projects of a similar nature, so should be taken as indicative only at this stage. In addition, costs associated with structural design, fire safety and other specialist design portions have been excluded at this stage (See section 14.1.1). It is recommended that a contractor is engaged to provide project specific costs to improve the accuracy of the business case.

The cost estimates also include a fee for FairHeat to manage and oversee the realisation of the works. This fee is based on hourly estimates for involvement on previous projects of similar size and scope.

All inputs and assumptions used in the analysis are set out within Appendix 7 – Techno-economic appraisal assumptions.

6.1. Risk mitigation works

6.1.1. Water quality

The recommended water quality works to mitigate the risks identified in Section 4.1 are outlined in Table 16.

Water quality improvement works are not always related to a direct reduction in operating costs and so costs have not been included in the NPV assessment in Section 6.2.

Instead, the cost of these works have been compared to the lost pipework value in the case that poor water quality reduces pipework lifespan to assess the potential benefits.

In this analysis the following assumptions have been made:

- In the case of pipework failure all riser and lateral pipework is replaced
- Replacement of riser pipework and all related works (e.g. insulation) has been based on costs from pipework replacement at other developments and has been costed at £500/m
- The expected pipework lifespan is 40 years

It is clear from the results in Table 17 that improving and maintaining water quality is a prudent investment, as any reduction in lifespan greater than 1 year due to water quality carries a greater cost than the proposed water quality improvement works.

It should be noted that additional measures would be required to ensure good water quality throughout the system's lifetime (e.g. regular sampling and dosing).

Item	Cost[1]
Install air and dirt separator in plant room	£6,900
Total cost	**£6,900**

1 – Excludes contingency and inflation

Table 16: Costs of recommended water quality risk mitigation works

Cost to improve water quality	Total cost of pipework replacement	Pipework value lost by reduced lifespan			
		1 year	5 years	10 years	15 years
£6,900	£1,196,800	£29,900	£149,600	£299,200	£448,800

Table 17: Results of the pipework replacement assessment

6.1.2. Other considerations

All further recommended interventions to mitigate the risks identified in Section 4.1 are detailed in Table 18.

Item	Cost[1]
Fix substation heat meters	£920
Install TMVs on bath outlets	£21,218
Install quick fill loop on cold water connection in plant room	£2,300
Decommission and remove 2 expansion vessels in plant room	£9,200
Total cost	**£40,538**

1 – Excludes contingency and inflation

Table 18: Costs of recommended other risk mitigation works

6.2. Performance improvement analysis

The inputs for the calculation of the net present value (NPV) of the proposed interventions have been calculated based upon the data provided by Leathermarket JMB and assumptions have been made where data has not been provided.

The financial inputs and assumptions are set out within Appendix 7 – Techno-economic appraisal assumptions for the following items:

- Capital costs of proposed interventions;
- Heat network loss model;
- Heat consumption;
- Pump energy consumption;
- Gas and electricity costs; and
- Maintenance costs.

All analysis has been conducted using the utility prices detailed in Table 19 as provided by Leathermarket JMB.

Gas price (p/kWh)	Electricity price (p/kWh)
8.78	33.05*

*Table 19: Year 1 utility costs used in financial analysis. *Electricity price was calculated using a weighted average of the day and night electricity rates and consumption data provided*

Data from the Green Book Supplementary Guidance Tables 4 (electricity) and 5 (gas) has been used to model the fuel costs over the NPV period. This allows the financial benefit of each work package to be calculated. Given the scale of uncertainty over future fossil fuel prices, there are multiple scenarios in the guidance tables which model different future gas and electricity cost trends that may occur.

Table 20 shows the different scenarios selected for gas and electricity for both the central and high cost assessments. The change in fuel prices throughout the NPV period, for both central and high cost assessments, is shown in Figure 10 and Figure 11 respectively. The year 1 energy costs are reflective of the costs highlighted in Table 19 for each assessment.

	Central cost assessment	High cost assessment
Gas	Central	High
Electricity	Central	High

Table 20: Scenarios used for central and high cost work package assessments from the Green Book Supplementary Guidance Tables 4 (electricity) and 5 (gas)

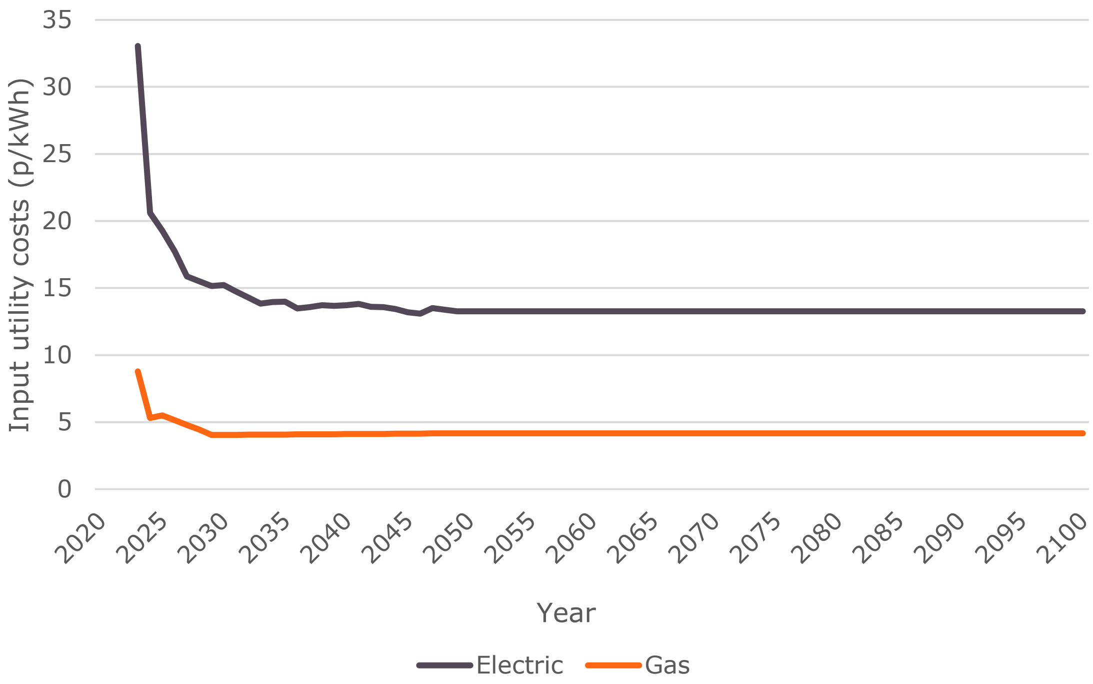

Figure 10: Predicted fuel costs for the central energy cost assessment from Green Book Supplementary Guidance Tables 4 (electricity - central) and 5 (gas - central)

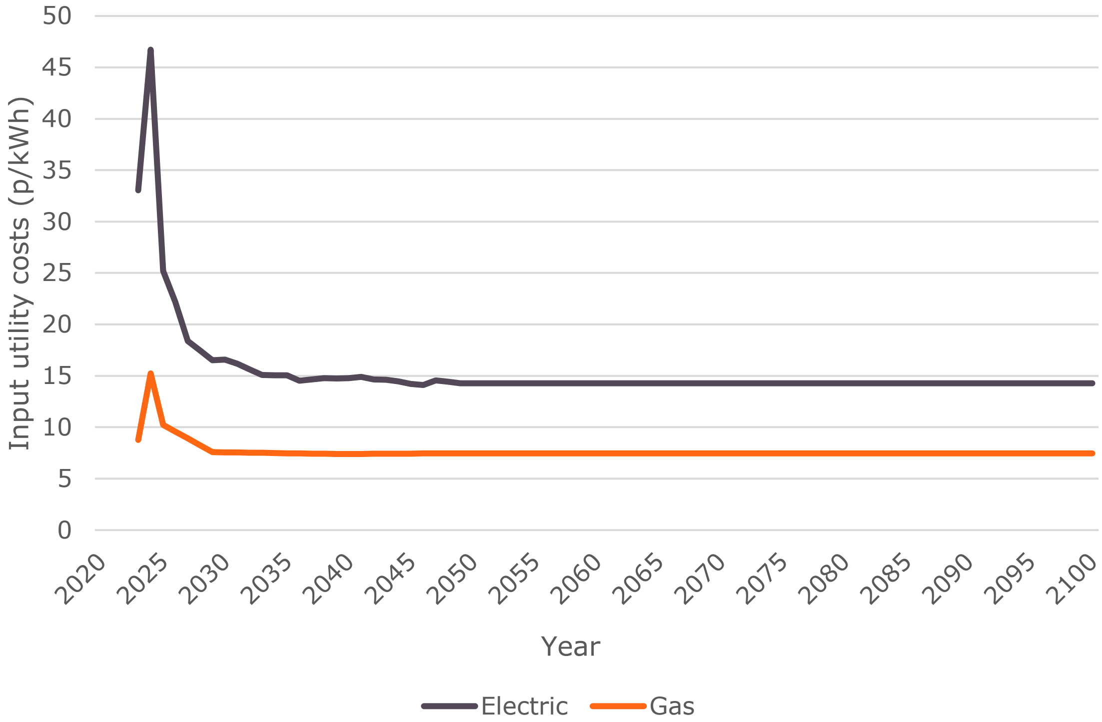

Figure 11: Predicted fuel costs for the high energy cost assessment from Green Book Supplementary Guidance Tables 4 (electricity - high) and 5 (gas - high)

6.2.1. Energy consumption

The estimated gas, pump electricity and carbon savings enabled by the work packages are set out in the tables below.

	Base Case	WP1	WP2	WP3
Gas consumption (kWh/year)	2,247,100	1,718,300	810,000	654,000
Reduction versus base case (%)	-	24%	64%	71%
Year 1 cost of gas (£/yr)	£197,340	£150,900	£71,130	£57,430

Table 21: Calculated gas consumption and year 1 costs for the current performance compared to the expected performance after Work Package implementation

	Base Case	WP1	WP2	WP3
Electricity consumption (kWh/year)	105,430	18,880	6,040	3,530
Reduction versus base case (%)	-	82%	94%	97%
Year 1 cost of electricity (£/yr)	£34,850	£6,240	£2,000	£1,170

Table 22: Calculated pump electricity consumption and year 1 costs for the current performance compared to the expected performance after Work Package implementation

	Base Case	WP1	WP2	WP3
Average carbon consumption (kg CO_2/year)	489,660	371,920	175,210	141,410
Reduction versus base case (%)	-	24%	64%	71%
Average annual cost of carbon (£/yr)	£160,400	£121,890	£57,420	£46,350

Table 23: Calculated carbon consumption and costs for the current performance compared to the expected performance after Work Package implementation. Average value reported to account for varying carbon intensity and cost over system lifespan.

6.2.2. NPV assessment of improvement options

The NPV assessment has been performed with a focus on 10- & 20-year timeframes following the implementation of the work packages. The original Meakin Estate heat network is c. 8 years old. Therefore, these timeframes allow the full lifecycle cost of replacing end of life equipment to be considered. It should be noted that assumptions regarding energy prices and future scheme use are less accurate over longer time periods.

Given the issues seen with the secondary pipework during the site audit, the plastic secondary pipework is likely to fail within the next 2-3 years. Work Package 2 proposes to decommission the space heating network, whilst Work Package 3 involves a full network retrofit with steel LTHW pipework. Thus, the secondary network pipework will require replacement between Years 2-3 of the analysis period, where it is not decommissioned/replaced as part of Work Package 2 or 3.

Due to the age and condition of the BMS and combined low loss header and air/dirt separator, this equipment is likely to fail within the next 5-10 years. All Work Packages propose to reinstate the BMS and a new air/dirt separator is to be installed as part of Work Package 3 (under water quality works – see Section 6.1.1), with the removal of the low loss header. It is estimated that if either of these works are not carried out, the corresponding items will require replacement between Years 5-10 of the analysis period.

Also, the substation heat meters were not operational at the time of the site audit. Therefore, the heat meters require replacement with separate units in Year 1 of the analysis where they are not repaired initially as part of any Work Package (under risk mitigation works – see Section 6.1.2).

These scenarios are outlined in Table 24, with a more detailed overview of replacement expenditure (REPEX) given in Section 14.1.3.

The cost of carbon has been excluded from the analysis as it does not have a direct financial impact.

Equipment item	Replacement unit cost	No. units	Start year	End year	Base Case	WP1	WP2	WP3
Heat meters	£1,500	4	1	1	X			
Plastic space heating pipework	£466,500*	-	2	3	X	X		
Plastic DHW pipework	£466,500*	-	2	3	X	X	X	
Combined low loss header & air/dirt separator	£10,000	1	5	10	X	X	X	
BMS	£50,000	1	5	10	X			

*Table 24: Equipment replacement scenarios implemented in NPV, with replacement start and end years of the analysis period given. *These are given as full retrofit costs for each individual secondary network*

6.2.2.1. Central energy cost assessment

The results of this assessment are shown in Table 25, and the NPV development of each Work Package is shown in Figure 12.

Work Package 2 generates a positive NPV over a 10- and 20-year period, with a simple payback time of 7 years. Work Packages 1 and 3 both produce negative NPVs over a 10-year period, but positive NPVs over a 20-year period, with simple payback times of 9 and 16 years respectively. Therefore, all work packages represent good investment opportunities at central energy costs. Work Package 2 achieves the most favourable NPV over the 20-year period and has the highest 20-year internal rate of return (IRR) of all work packages.

	WP1	WP2	WP3
Capital cost	£417,400	£1,157,200	£2,243,000
10 Year NPV	-£17,900	£141,500	-£290,900
10 Year IRR	2.6%	6.5%	0.0%
20 Year NPV	£204,400	£669,000	£385,800
20 Year IRR	8.8%	11.2%	6.1%
Simple payback (years)	9	7	16

Table 25: NPV and IRR for optimisation investments - central energy cost scenario (excluding the cost of carbon)

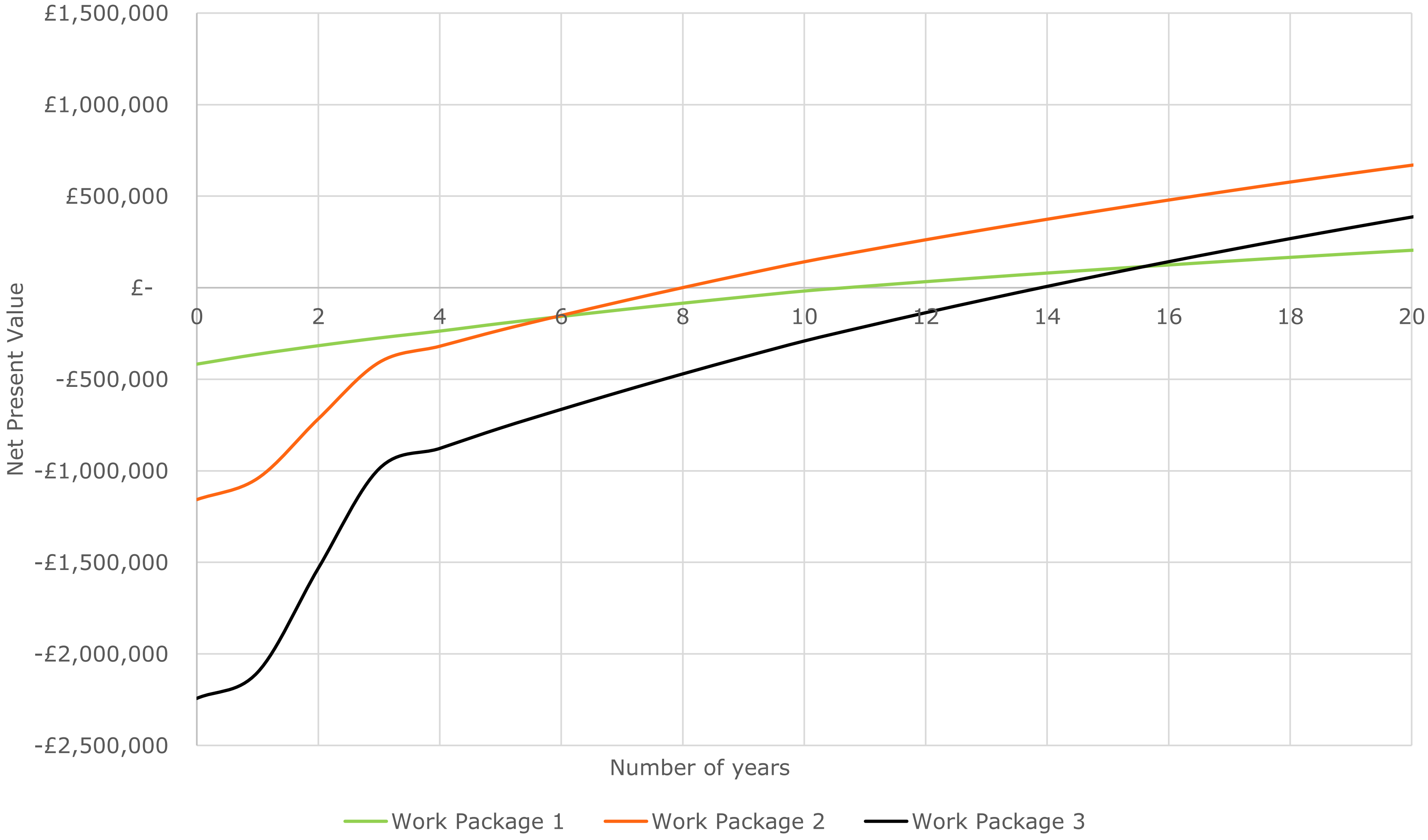

Figure 12: NPV development over 20 years for each Work Package - central energy cost scenario

6.2.2.2. High energy cost assessment

The results of this assessment are shown in Table 26, and the NPV development of each Work Package is shown in Figure 13.

In the high energy cost scenario, all work packages produce positive NPVs over a 10- and 20-year period. Work Packages 1, 2 & 3 have simple payback times of 5, 4 and 6 years respectively. Therefore, all Work Packages therefore represent good investment opportunities again, with Work Package 2 achieving the most favourable NPV over the 20-year period and displaying the highest 20-year IRR.

	WP1	WP2	WP3
Capital cost	£417,400	£1,157,200	£2,243,000
10 Year NPV	£221,600	£733,000	£361,100
10 Year IRR	14.3%	18.0%	7.6%
20 Year NPV	£553,500	£1,549,800	£1,358,000
20 Year IRR	18.1%	20.8%	12.0%
Simple payback (years)	5	4	6

Table 26: NPV and IRR for optimisation investments - high energy cost scenario (excluding the cost of carbon)

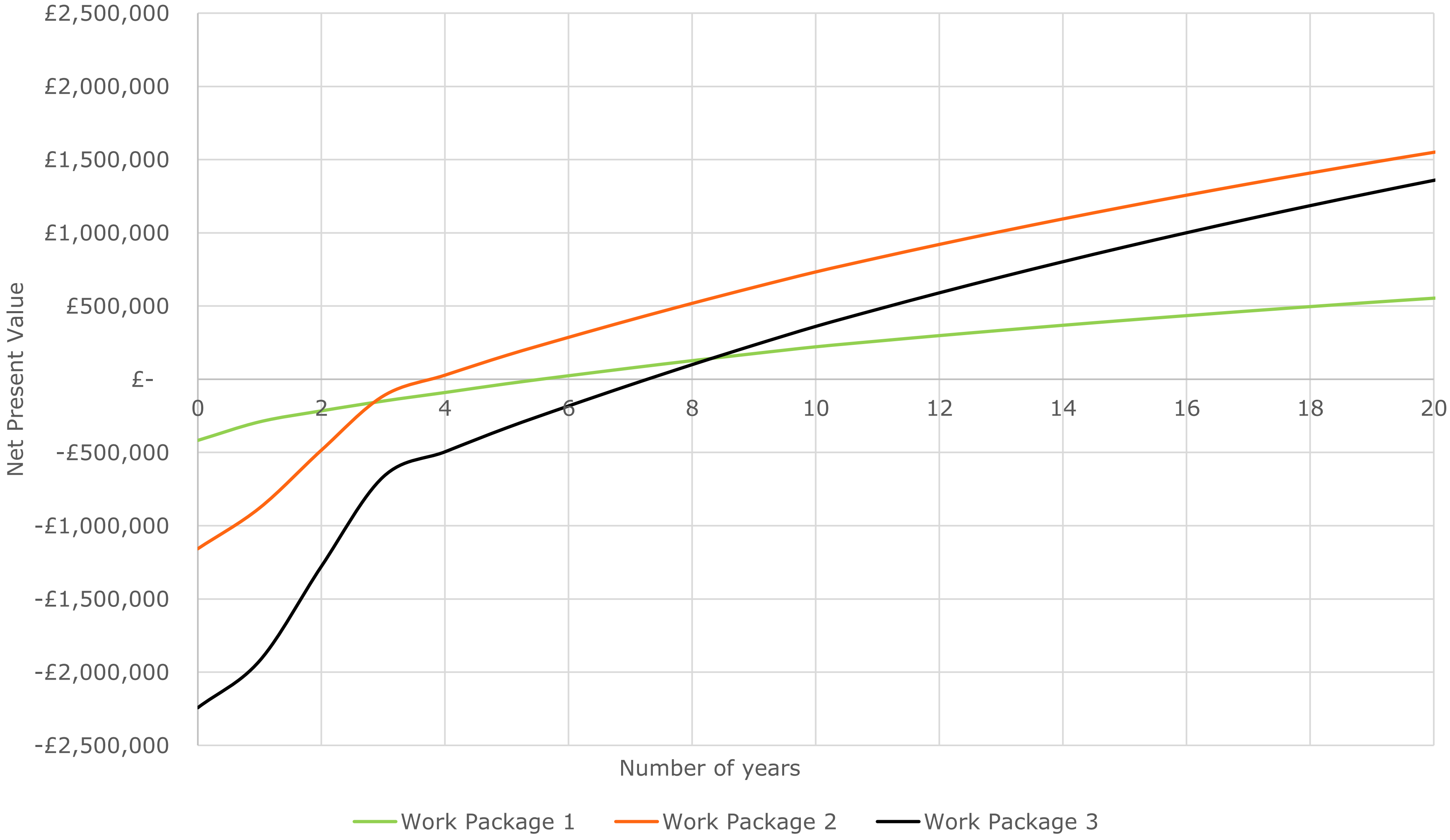

Figure 13: NPV development over 20 years for each Work Package - high energy cost scenario

6.2.3. Impact of external funding on NPV

Works that improve the efficiency of the Meak Estate heat network would qualify for funding under the Heat Network Efficiency Scheme (HNES). As such, the NPV of the Work Packages has been analysed on the basis that 50% of eligible capital costs are recuperated from external funding streams.

It should be noted that the capital costs for replacing the radiators and boilers (in Work Package 3) are not eligible for funding under HNES and Leathermarket JMB will need to fund these separately if Work Package 3 is selected. As such, the costs of replacing radiators in dwellings and boilers in the plant room have been included within the total capital costs, however these specific costs are the only items which are not discounted by 50%.

6.2.3.1. Central energy cost assessment, with external funding

The results of this assessment are shown in Table 27, and the NPV development of each Work Package in this scenario is shown in Figure 14.

Again, all work packages produce a positive NPV over a 10- and 20-year period. Work Packages 1, 2 and 3 have simple payback times of 5, 3 and 3 years respectively. Thus, all work packages represent good investment opportunities. With external funding, Work Package 3 now achieves the most favourable NPV over the 20-year period, whilst Work Package 2 still has the highest IRR of all work packages.

	WP1	WP2	WP3
Capital cost	£208,700	£578,600	£1,211,000
10 Year NPV	£190,800	£720,100	£741,000
10 Year IRR	19.5%	30.2%	18.4%
20 Year NPV	£413,100	£1,247,600	£1,417,800
20 Year IRR	22.5%	31.6%	20.7%
Simple payback (years)	5	3	3

Table 27: NPV and IRR for optimisation investments considering HNES funding – central energy cost scenario (excluding the cost of carbon)

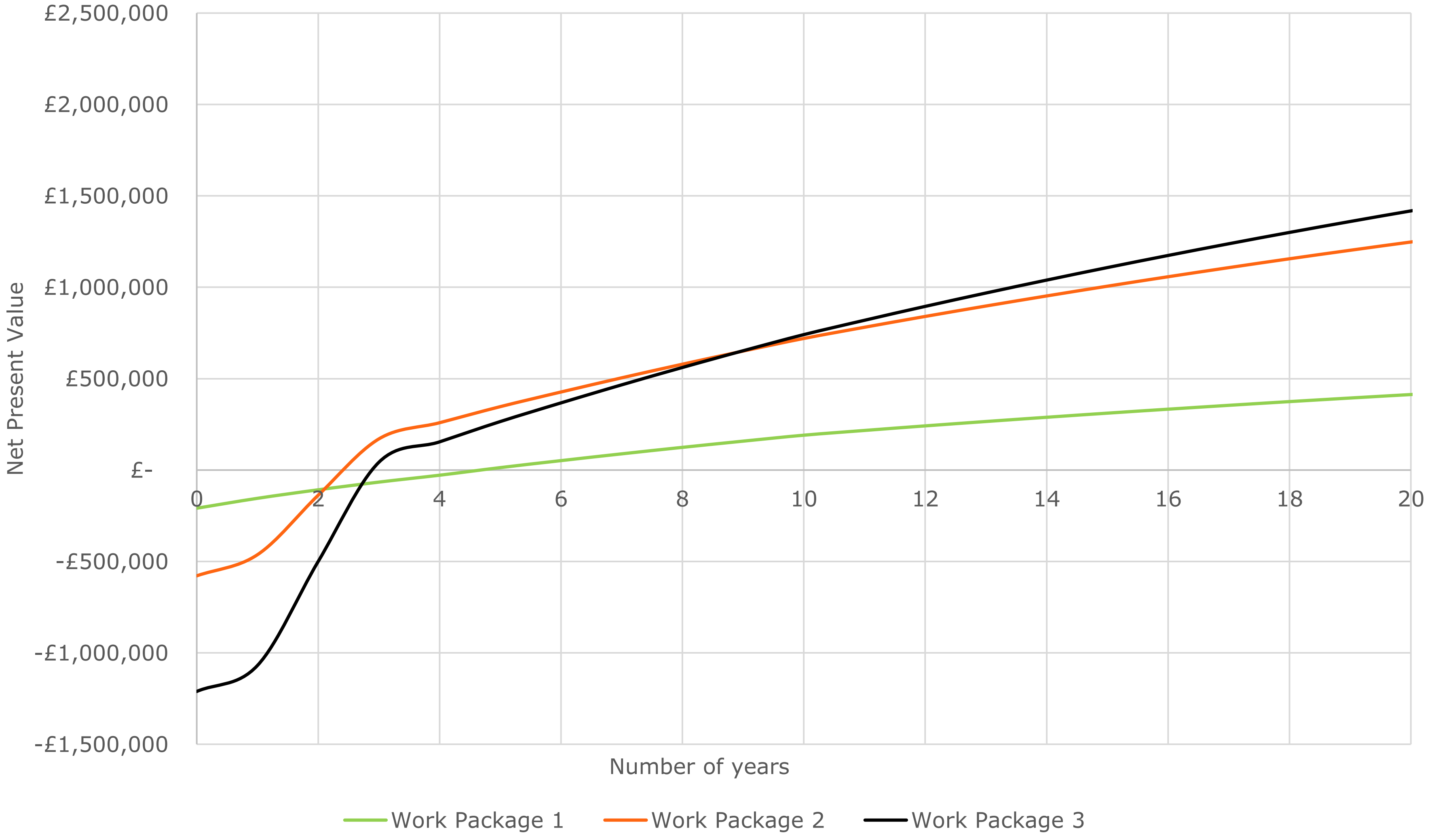

Figure 14: NPV development over 20 years for each Work Package – central energy cost scenario with external funding

6.2.3.2. High energy cost assessment, with external funding

The results of this assessment are shown in Table 28, and the NPV development of each Work Package in this scenario is shown in Figure 15.

Once again, all three work packages produce a positive NPV over a 10- and 20-year period. Work Packages 1, 2 and 3 have simple payback times of 2, 2 and 3 years respectively. Therefore, all work packages represent good investment opportunities. As before, Work Package 3 achieves the most favourable NPV over the 20-year period and Work Package 2 has the highest rate of return.

	WP1	WP2	WP3
Capital cost	£208,700	£578,600	£1,211,000
10 Year NPV	£430,300	£1,311,600	£1,393,100
10 Year IRR	42.2%	51.2%	30.1%
20 Year NPV	£762,200	£2,128,400	£2,390,000
20 Year IRR	43.2%	51.6%	31.4%
Simple payback (years)	2	2	3

Table 28: NPV and IRR for optimisation investments considering HNES funding – high energy cost scenario (excluding the cost of carbon)

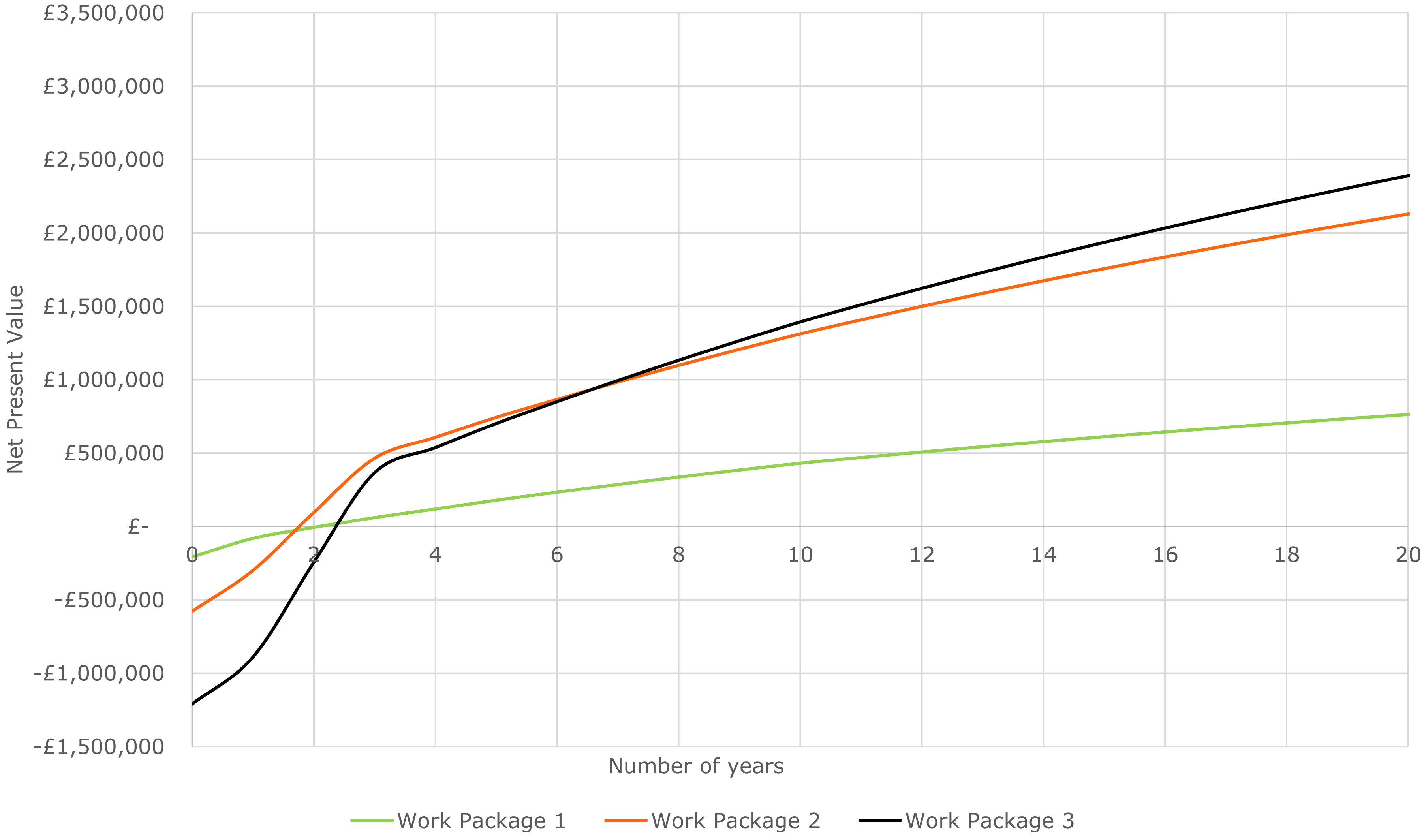

Figure 15: NPV development over 20 years for each Work Package – high energy cost scenario with external funding

6.2.4. Sensitivity analysis

In order to determine the magnitude of the effect of certain factors (CAPEX, Discount Rate, Gas Price and Electricity Price) of the appraisal model on the NPV appraisal, a sensitivity analysis exercise has been undertaken. The analysis has been carried out for each of the work packages.

The impact on the 20-year NPV has been used to quantify the sensitivity of the NPV calculation, with the sensitivity of the model assessed individually for each factor. For each factor, a ±20% variation was made to investigate the impact on the NPV appraisal.

6.2.4.1. Central energy cost assessment

The results of the Sensitivity Analysis in Figure 16 are presented as the alternative result of the 20-year NPV, compared against the base case NPV for the central energy cost scenario.

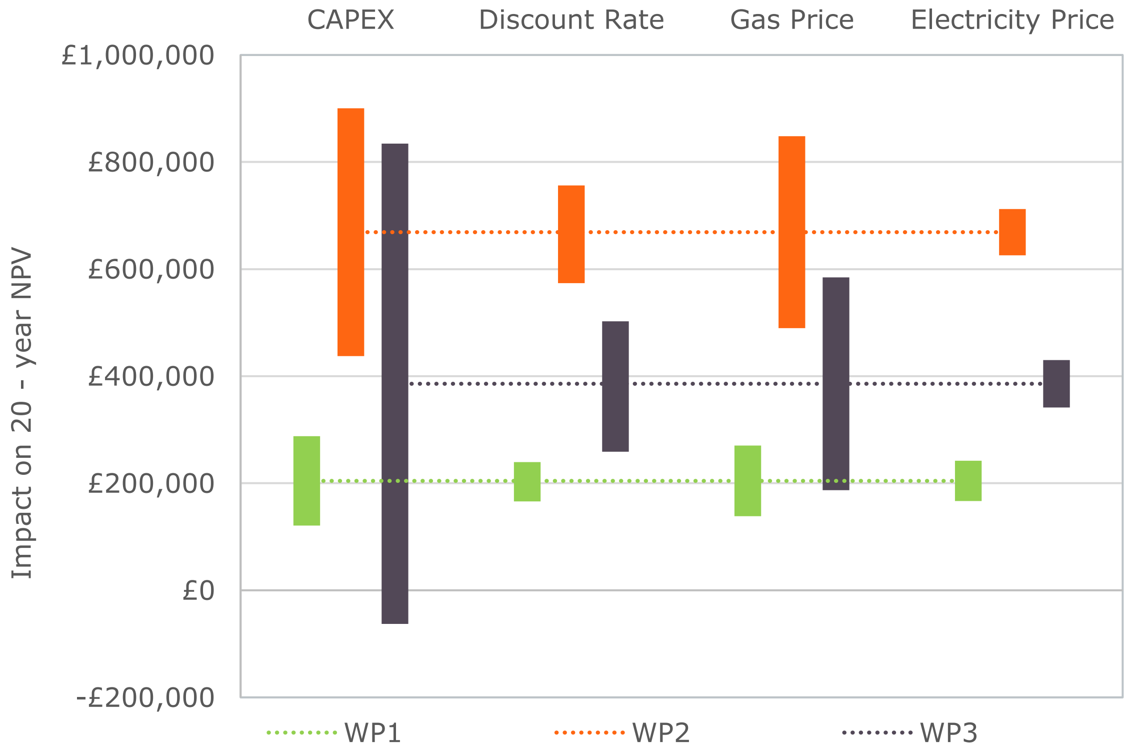

Figure 16: Sensitivity analysis on a 20-year NPV calculation – central energy cost scenario

6.2.4.2. Central energy cost assessment, with external funding

The results of the Sensitivity Analysis in Figure 17 are presented as the alternative result of the 20-year NPV, compared against the base case NPV for the central energy cost scenario, with external funding. In this case, the Sensitivity Analysis has been conducted on the basis that 50% of eligible capital costs are recuperated from external HNES funding.

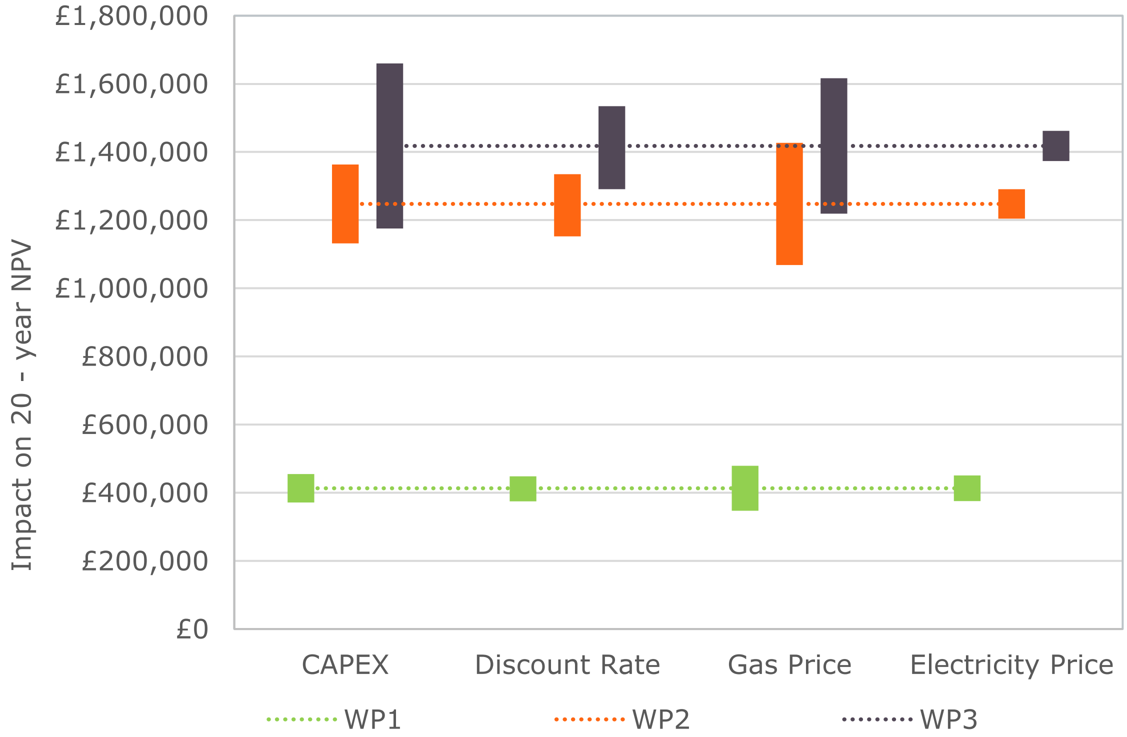

Figure 17: Sensitivity analysis on a 20-year NPV calculation – central energy cost scenario with external funding

6.2.4.3. High energy cost assessment

The results of the Sensitivity Analysis in Figure 18 are presented as the alternative result of the 20-year NPV, compared against the base case NPV for the high energy cost scenario.

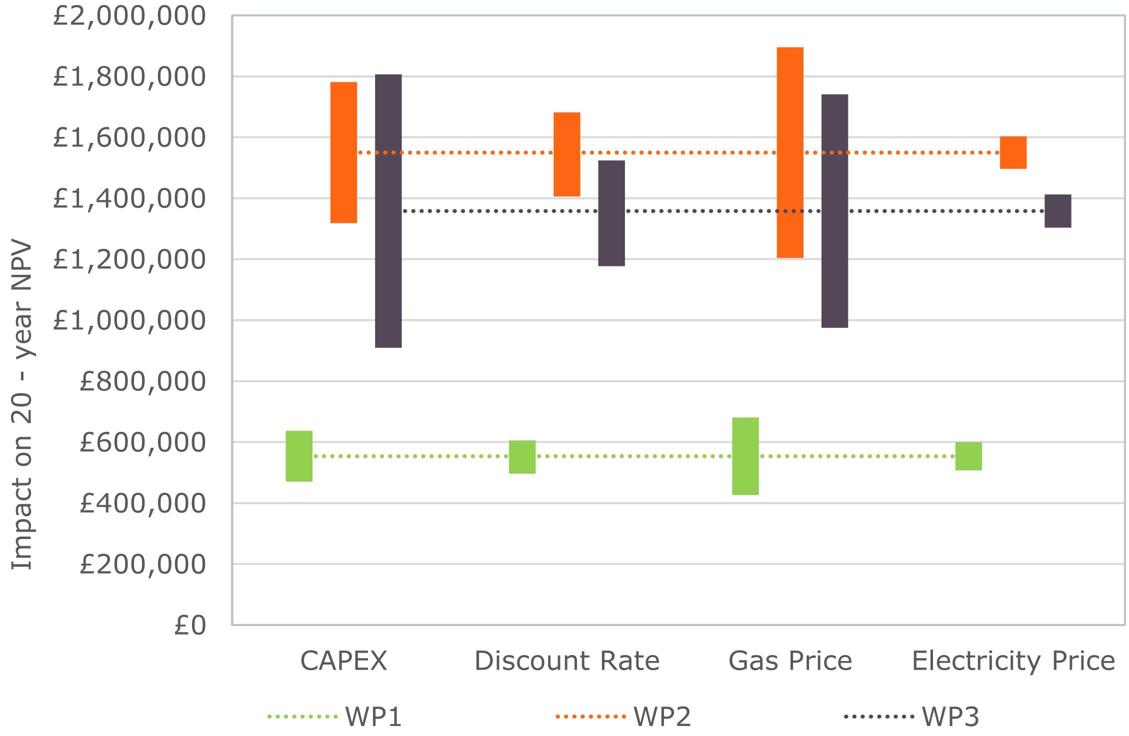

Figure 18: Sensitivity analysis on a 20-year NPV calculation – high energy cost scenario

6.2.4.4. High energy cost assessment, with external funding

The results of the Sensitivity Analysis in Figure 19 are presented as the alternative result of the 20-year NPV, compared against the base case NPV for the high energy cost scenario, with external funding. In this case, the Sensitivity Analysis has been conducted on the basis that 50% of eligible capital costs are recuperated from external HNES funding.

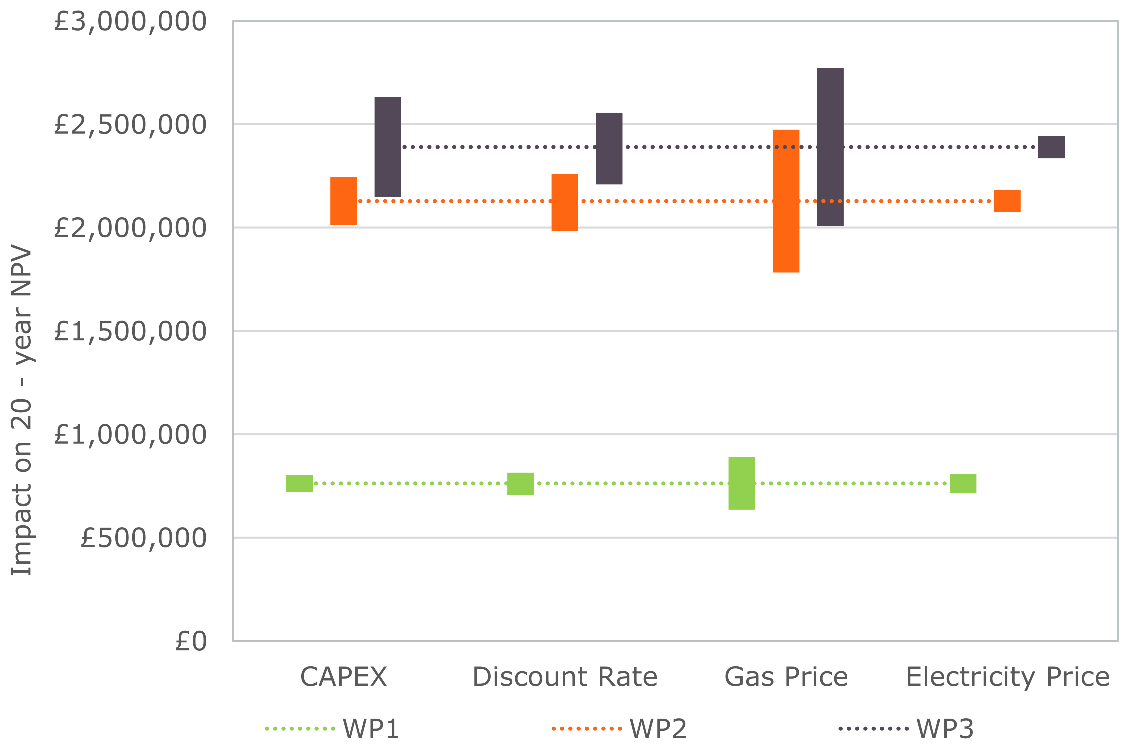

Figure 19: Sensitivity analysis on a 20-year NPV calculation – high energy cost scenario with external funding

6.2.4.5. Sensitivity analysis conclusion

The sensitivity analysis shows that, in all scenarios, Work Package 3 is most sensitive to gas price and CAPEX, whilst discount rate and electricity price have the least overall effect on the 20-year NPV. Additionally, Work packages 2 & 3 are moderately sensitive to discount rate, particularly in high energy cost scenarios. For Work Packages 2 and 3, electricity price has the least overall impact across all modelled scenarios.

The assessment confirms that both unfunded scenarios retain a positive 20-year NPV for Work Packages 1 and 2 across their entire ±20% variations. For Work Package 3, a positive 20-year NPV is achieved across the entire ±20% variation in the high energy cost scenario, whereas this is positive for most of the variation for the central cost case (depending on CAPEX).

For the externally funded scenarios, all Work Packages provide a positive 20-year NPV across the entire ±20% variation.

6.3. Techno-economic analysis conclusions

Without external funding, only Work Package 2 produces a positive NPV over a 10- and 20-year period in both energy cost scenarios. Of all work packages, Work Package 2 achieves the most favourable NPV over the 20-year period and has the highest rate of return in both energy cost scenarios.

Works that improve the efficiency of the site would qualify for funding under the Heat Network Efficiency Scheme (HNES). If funding is secured, then 50% of eligible capital costs are recuperated from external funding streams. As a result of this, the simple payback time of the project will approximately half for all energy price scenarios.

It should be noted that the capital costs for replacing the radiators and boilers (in Work Package 3) are not eligible for funding under HNES and Leathermarket JMB will need to fund these separately if Work Package 3 is selected. As such, the costs of replacing radiators in dwellings and boilers in the plant room have been included within the total capital costs, however these specific costs are the only items which are not discounted by 50%.

For both the central and high cost scenarios, the NPVs increase substantially over both the 10- and 20-year periods for each work package, when accounting for funding. All work packages generate a positive NPV over a 20-year period in both energy cost scenarios. With funding, Work Package 3 produces the most favourable NPV over a 20-year period in the both energy cost scenarios. However, Work Package 2 retains the highest internal rate of return in both cost scenarios.

As all options will benefit notably when taking the HNES funding into account, it is recommended that this is pursued regardless of work package selection.

Work Package 1 provides the least performance benefit and generates the worst financial outcome in most cost scenarios. Therefore, FairHeat conclude this to be the least feasible solution if a long term, robust engineering solution is preferred, as it retains the risks associated with the plastic secondary network pipework, and a degree of poor performance related to retaining the 4-pipe system.

Despite generating the best financial outcome in most cost scenarios, Work Package 2 still presents the same leak risk that the plastic secondary network pipework presents. The works in this work package should only be considered as a short term solution if large investment into performance improvement is not possible for the next 1 or 2 years. Although it presents a solid financial investment, the risk associated with this Work Package will be elevated, and it is likely that the pipework will need replacing shortly after completion of the works. Although it could be considered a stepping stone towards full a retrofit, as detailed in Work Package 3, this approach may extend resident downtime further than necessary.

Although significant capital investment is required, Work Package 3 provides a much more robust solution from an engineering perspective and presents a financially viable investment. If Funding is received, Work Package 3 provides the most favourable NPV over 10 and 20 years. Therefore, FairHeat would be confident in this work package achieving a permanent long-term benefit to Leathermarket JMB and their residents. As Work Package 3 enables a reduction in flow temperature to improve the feasibility of heat pump installation and efficient heat generation, Work Package 3 is recommended.

6.4. Regulatory considerations

OFGEM have been appointed as the Heat Networks Regulator for Great Britain. This regulation is currently being drafted and is expected to come into force in 2025 as per the Energy Act 2023. As part of this, a technical standard for heat network design and operation is being developed. The standard, being developed by the Heat Network Technical Assurance Scheme, will initially only affect new developments. However, there will also be provisions within the regulations to retrospectively apply minimum performance requirements to existing schemes to provide customer protection. This is currently expected to come into effect in 2028, although this has not yet been confirmed.

As such, if no works are undertaken at this time, there is a risk that that these works will have to be undertaken in the future to ensure compliance with heat network regulations.

6.5. Overall cost of works

The total cost of all risk mitigation and performance improvement works is summarised in Table 29.

Risk mitigation works are eligible for funding under HNES, so the revised capital cost in the event of a successful funding application is also detailed below.

	WP1	WP2	WP3
Water quality works	£7,000	£7,000	£7,000
Recommended other considerations	£34,000	£34,000	£34,000
Performance improvement works	£203,000	£656,000	£1,360,000
Cost of design, engineering support & delivery	£165,000	£364,000	£618,000
Sub-total	**£409,000**	**£1,061,000**	**£2,019,000**
Contingency & inflation	£55,000	£142,000	£270,000
Total	**£463,000**	**£1,203,000**	**£2,289,000**
Costs not eligible for HNES funding	-	-	£179,000
HNES funding available (46-50% of eligible costs)	£231,000	£601,000	£1,055,000
Total with HNES funding	**£232,000**	**£602,000**	**£1,234,000**

Table 29: Total cost of all risk mitigation and performance improvement works

7. Delivery plan

This section provides an overview of key considerations and next steps in delivering the recommended system interventions.

7.1. Phasing of works

It is important that the phasing of works follows the principles for improving network performance. As discussed in Section 3.1, interventions should be split into stabilising measures, easy wins, and longer-term continuous improvement processes.

Stabilizing actions may be required immediately to rectify or avoid heat network failure. The water quality and risk mitigation items highlighted within this report should therefore be prioritised in the phasing of works.

Easy wins should be pursued following network stabilisation, as these interventions will offer fast improvements in performance for limited cost.

Continuous improvement of networks will occur in the medium to long term and will be implemented to gradually improve network performance.

This approach to project phasing should be considered during design development of the selected work package and the final design documentation should outline key considerations for sequencing of works.

7.2. Availability of funding

The delivery of interventions will depend on the availability of internal or external (such as grants) funding. As such, high cost activities may need to be delayed until funds are available.

As discussed in Section 6.2.3, measures proposed in this report would be eligible for up to 50% funding for Work Packages 1 and 2, and 46% for Work Package 3, via the HNES scheme.

A recommended approach to the works proposed would be to carry out any stabilisation measures as soon as possible.

Easy win and continuous improvement measures typically require more planning and design input than the stabilisation stage. It would be recommended to go for these measures under the HNES scheme funding. The design for these works can be considered while waiting for the appropriate funding to become available.

7.3. Procurement

For small projects, organizations may have the flexibility to directly award contracts to their existing supply chain. This approach allows them to work with trusted contractors who have previously demonstrated their capabilities and reliability, streamlining the procurement process and expediting project execution.

For larger district heating projects, it is likely that a more formal tender and procurement process will be required. If this approach is required, it should be ensured that the quality of the contractor and their approach to delivering works to a high standard is suitably considered alongside the cost comparison. To achieve this, it is recommended that the tender process includes the following:

- Clearly defined quality requirements
  - Clearly defining the quality requirements and expectations for the project sets the foundation for evaluating contractor proposals. This includes specifying technical standards, performance criteria, certifications, and any specific quality assurance processes that should be followed.
- Incorporating quality criteria in evaluation
  - Including quality criteria as a significant factor in the evaluation process ensures that quality considerations are given proper weightage alongside other factors such as cost. Assigning appropriate importance to quality-related factors when scoring and comparing contractor proposals helps in selecting contractors who prioritize and demonstrate a commitment to quality.
- Technical competence and expertise
  - Assessing the technical competence and expertise of potential contractors is crucial for ensuring quality outcomes. Evaluating their track record, experience in similar projects, adherence to quality standards, and relevant certifications or accreditations provides insights into their ability to meet the organization's quality requirements and deliver high-quality work.

In both procurement routes, it is essential that organizations consider factors such as the contractor's track record, relevant experience in district heating projects, technical capabilities, financial stability, and adherence to safety and quality standards.

Based on the scale of the measures proposed, it is expected that works at Meakin Estate will require a full tender procurement route, but this should be confirmed with the relevant internal stakeholders.

7.4. Lifecycle considerations

Given FairHeat's previous experience on other projects, the age of the Meakin Estate network and issues with the secondary pipework seen during the site audit, the plastic secondary pipework is likely to fail within the next 2-3 years. As such, is has been estimated that, if decommissioning and replacement of this pipework is not carried out, a full network retrofit will be required in the next 2-3 years.

Due to the condition of the BMS and combined low loss header and air/dirt separator during the site audit, these pieces of equipment are likely to fail within the next 5-10 years. Consequently, FairHeat have estimated that if the BMS is not reinstated and an air/dirt separator is not installed (separate to the low loss header), both items will likely need a replacement within 5-10 years from now.

Also, since the substation heat meters were not operational during the site visit, new heat meters will need to be installed in the first year of works, if they are not fixed as part of the risk mitigation works (see Section 14.1.5).

For each piece of equipment, this REPEX has not been modelled in the NPV for work packages where that piece of equipment is due to be repaired, replaced or removed. These scenarios have been detailed in Section 6.2.2.

The impact of these works should be considered when selecting a performance improvement strategy moving forward.

7.5. Portfolio planning

The recommendations for this site need to be balanced with interventions required on other sites that Leathermarket JMB operates. When determining the order in which measures are actioned and sites addressed, the following should be considered:

- Portfolio value assessment
  - Assess the value of proposed works within the context of the entire heat network portfolio. Prioritize projects that offer the greatest potential for overall network performance improvement or have strategic importance.
- Pilot Interventions
  - Consider piloting specific interventions on a single site before implementing them across the wider portfolio. This allows for the evaluation of efficacy, performance, and potential challenges on a smaller scale. Piloting interventions helps in identifying any necessary adjustments or improvements before scaling them up to other sites, minimizing risks and optimizing outcomes.
- Site based vs Stabilization and easy wins prioritisation
  - Heat network optimisation projects can either be carried out site by site, or stabilisation and easy wins could be implemented across the portfolio before moving to more intrusive continuous improvement works. Prioritizing easy wins can generate early successes, build momentum, and demonstrate tangible benefits, providing a positive impact on the overall optimization process. However, this approach requires more up front planning, coordination with site staff and can increase project complexity if a large number of sites are targeted at the same time
- Resource allocation
  - Allocate resources effectively to balance the delivery of optimization works across multiple sites. Consider factors such as available budget, workforce capacity, and time constraints when determining the sequencing and phasing of works. This ensures that resources are appropriately allocated to address the most critical sites while also considering long-term goals for the entire portfolio.
- Resident impact
  - Prioritisation of works should consider the impact to residents. Works which offer the most effective means of reducing risk to residents and improving the cost and reliability of service should be prioritised. However, it should also be noted that splitting intervention works on a site into separate projects over a longer period of time creates additional disruption for residents and increases the cost and complexity of resident communications. Additional consideration should be given to vulnerable residents or 'customers in need' to ensure their needs are factored into decision making.

The main barrier in effective portfolio planning is often a lack of understanding of the extent of issues across each site, meaning several of the considerations above cannot be suitably addressed. In these instances, it is recommended that a KPI driven high level portfolio assessment of all heat networks is undertaken. This would provide a holistic understanding of the portfolio, enabling the identification of common trends and helping to prioritize underperforming networks and areas with the highest potential for improvement.

7.6. FairHeat delivery model

To support delivery of the works outlined above, FairHeat offer a full project delivery service and can be procured to deliver works in accordance with the deliverables contained within this document.

Upon appointment, the following can be undertaken:

- Carry out a full tender exercise utilising our supply chain, ensuring that alignment with procurement processes and individual needs.
- Upon approval, selection, appointment and management of all contractors.
- Procurement of all plant, equipment & resource requirements.
- Project management of the full delivery & provide quality assurance from cradle to grave.
- The costs for these activities are included within the project capital cost estimate.

In addition to the traditional model above, a cost authorisation (CA) process can be offered which is part of a NEC4 contract. This ensures full transparency of activities, supply chain and FairHeat costs, and facilitates cost tracking.

At a high level this process is as follows:

- Clients are given access to FairHeat Shared drive and allocated a dedicated folder.
- CAs are raised to ensure agreement on scope of works, programme & contractor selection.
- CAs are raised for each activity (these include supply chain quotations/costs where applicable).
- CAs are signed off by FairHeat & the Client.
- All activities are recorded on a CA register.
- The Client provides a PO for the whole project or individual packages.
- Monthly payment applications are submitted to Client PM for processing – these are all drawn down from approved CAs.

FairHeat can either be directly appointed, or to facilitate internal procurement, appointed via the Crown Commercial Services (CCS) website as a preferred supplier on the Demand Management & Renewables (DMR) RM6314 Framework.

This framework provides the option to either apply for Capital works Government funding or appoint a preferred supplier for the project. The framework is available for both public and private clients.

Should this route be used, further guidance notes can be provided.

8. Appendix 1 – Optimisation study process overview

	Pre-project	Phase 1: Initial investigation				Phase 2: Techno-economic options appraisal			Phase 3: Implementation plan	
	0. Define project	1. Information & data collection	2. Pre-audit analysis	3. Site audit	4. Technical review	5. Detailed technical analysis	6. Determine potential interventions	7. Cost benefit analysis	8. Costing of interventions	9. Final business case
Stage outcome	Understand Client aims & agree project scope	All relevant information on heat network identified	Initial understanding of system issues and potential causes	Sufficient understanding of system to complete optimisation assessment	Gain qualitative understanding of system issues	Quantitative assessment of performance against KPIs completed	Optimisation opportunities developed and modelled	Initial business case for optimisation opportunities completed	Detailed costing of interventions to inform final business case	Final business case for optimisation opportunities completed
Core tasks	Initial engagement Understand heat network typology and issues	Issue & return RFI Collect M&B and O&M data	Analyse all information returned from RFI Interview Client to understand issues from Client perspective Data gap analysis	Organise site visit and dwelling access Undertake site audit Measurements of key parameters (e.g. temperatures) Meeting and discussing performance with end users	Review of information site audit and pre-audit analysis Develop hypotheses regarding probably causes of performance issues Presentation of findings Discuss queries with manufacturers	Undertake root cause analysis Heat loss modelling Pump energy modelling Analysis of reliability and financial KPIs	Selection and design assessment of interventions Heat loss modelling Pump energy modelling Analysis of reliability and financial KPIs	Financial modelling of work packages Produce business case	Develop high level scope of works Engage with contractor and equipment suppliers to cost for works Undertake pilot of works if appropriate to assist with costing & confirming impact of interventions	Financial modelling of work packages Produce delivery plan Update business case
Information exchanges	High level summary of issues Scope and quote	Heat network documentation Heat meter data BMS data O&M logs	Queries raised during analysis	Requirements to ensure successful site audit RAMS	Findings of site audit		Client feedback on intervention options	Client inputs into financial model	Information for costing Data collected during and following pilot (if conducted)	Client inputs into financial model
Key outputs	Defined project scope Engagement to undertake optimisation study	RFI register & gap analysis	Draft system issue list Data gap analysis results	Completed site audit checklists	Initial investigation report Presentation of findings Decision on next steps	Heat loss model KPI analysis	Work package selection Heat loss model KPI analysis	Techno-economic options appraisal report Presentation of findings Decision on next steps	High level scope of works Detailed interventions cost plan Post-pilot report	Implementation plan Presentation of findings Decision on next steps

Table 30: Summary of key optimisation study stages

9. Appendix 2 – List of plant room equipment

Equipment	Make/model	Quantity
Gas boilers	Potterton Commercial NXR 5i-23 Riello RS 100/M (burner)	2
Boiler shunt pumps	Grundfos MAGNA3 65-150 F	2
Network pumps	Grundfos TPE 100-250/2	2
Pressurisation unit	Mikrofill 3	1
Expansion vessel	Mikrofill 130 Mikro-Pro 800 L	4
Dosing pot	Fabricated Products 10L	1
Air/dirt separator	Spirotech Spirocross XC150F	1
Heat meter	Sontex Supercal 531	1
Insulation	Unknown make – mineral wool (50 mm)	-
BMS	Gemco ECS Ltd – unknown model Trend iQVIEW8 (panel)	1

Table 31: List of plant room equipment

10. Appendix 3 – Schematics and Layouts

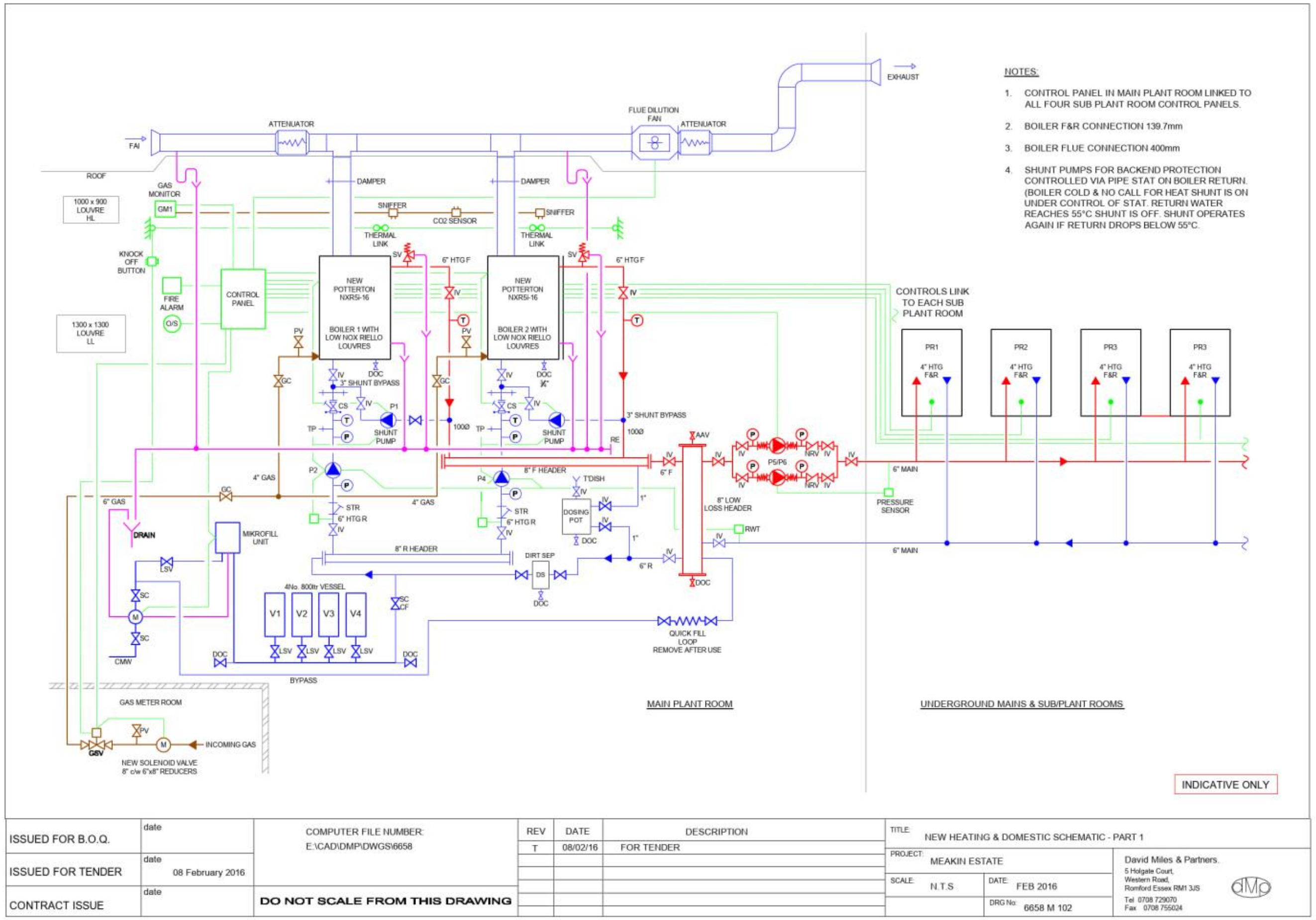

Figure 20: Schematic provided for plant room

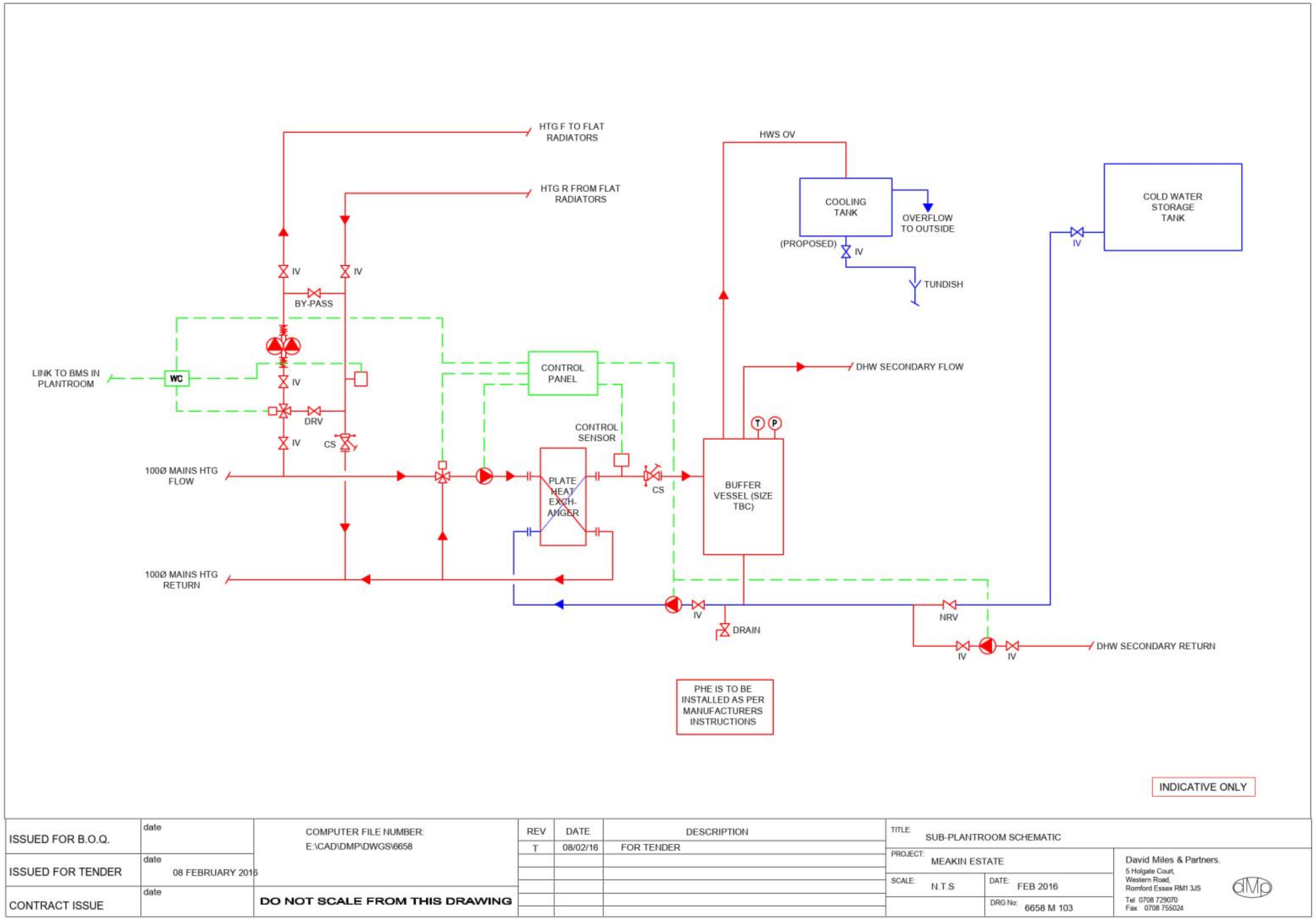

Figure 21: General schematic provided for substation

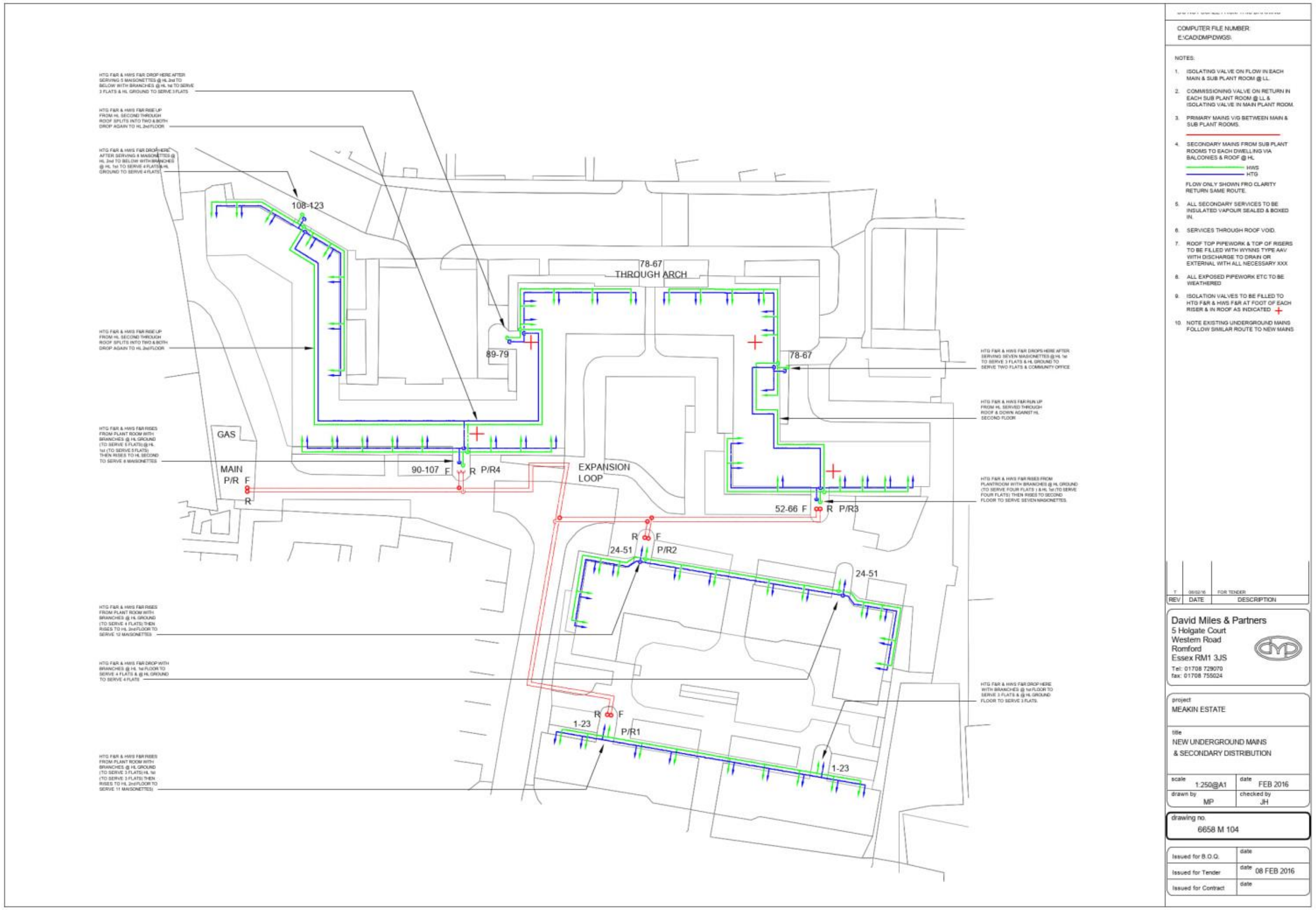

Figure 22: Sitewide layout provided with distribution pipework routing and substation locations

11. Appendix 4 – Site photos

11.1. Dwelling

Figure 23: Fixed bypasses on DHW and space heating pipework behind wall panel, with one of the bypass legs removed (left)

Figure 24: TRV with valve head/actuator removed, leading to reduced space heating control

11.2. Network

Figure 25: Plastic secondary network pipework leaving a substation

Figure 26: Fixed bypass on uninsulated external network pipework

Figure 27: Nitrile rubber insulation on lateral pipework, with sections uninsulated

11.3. Substation

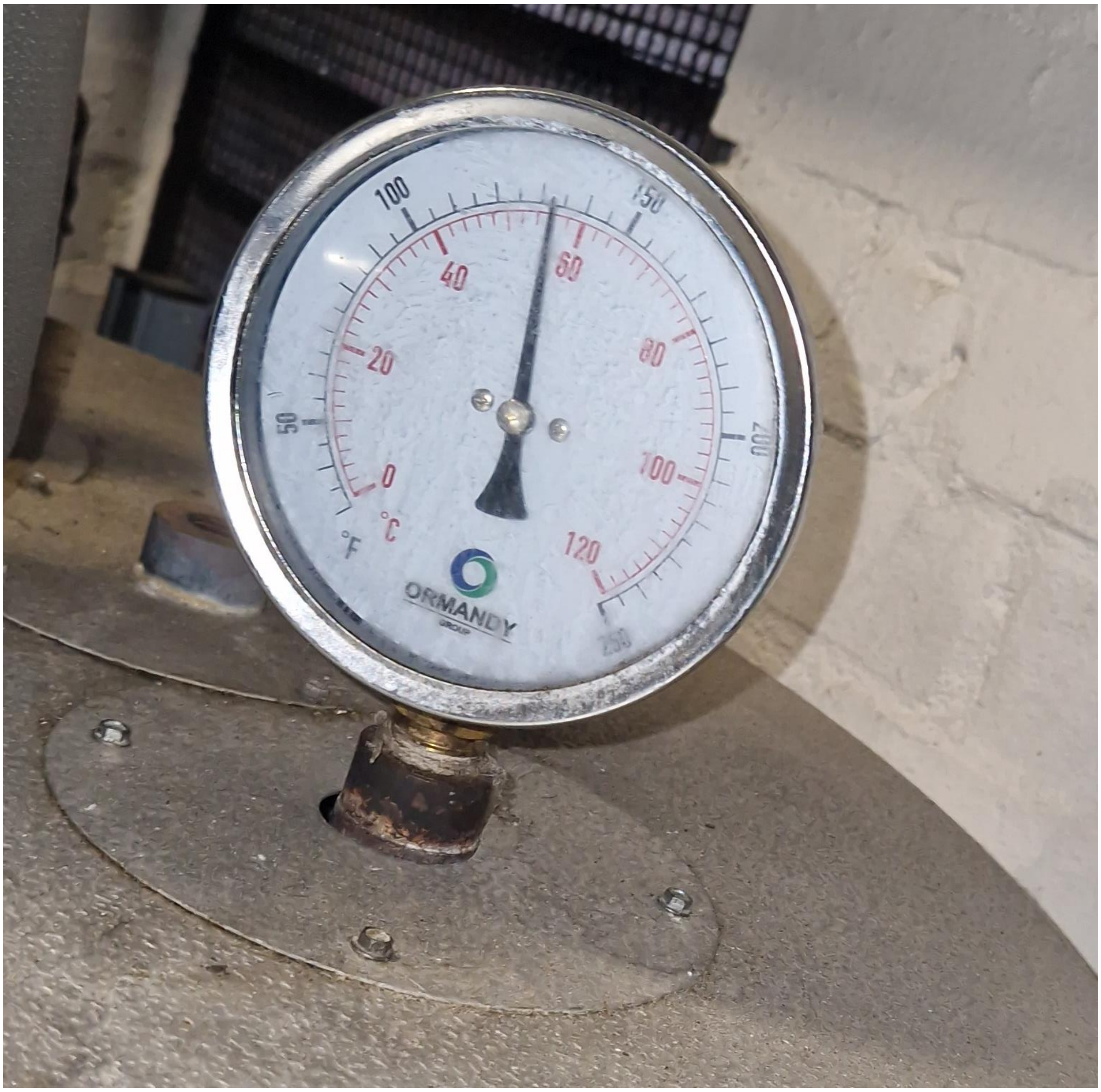

Figure 28: DHW calorifier storing hot water at ~56°C, which is unacceptably low

Figure 29: DHW plate heat exchanger with 3-port valve actuator missing

Figure 30: Heat metering installed but with errors preventing data reads

11.4. Plant room

Figure 31: Combined low loss header and air/dirt separator

Figure 32: One network pump electrically isolated, leading to no redundancy

Figure 33: Dosing pot installed across flow and return pipework, creating a bypass leg (and a dead leg when isolated)

12. Appendix 5 - Peak load calculation methodology

The peak load demand calculation has been based on the CP1 2020 DHW and space heating sizing approach.

All inputs and assumptions used during the calculations are detailed in Table 32.

Item	Value	Reference
Number of dwellings	123	Accommodation schedule
Number of bathrooms in each dwelling	1/2 (depending on dwelling type)	Layout drawings
Kitchen outlet flow rate	6 l/min	NHBC
Bath outlet flow rate	9 l/min	NHBC
Shower outlet flow rate	8 l/min	NHBC
LTHW flow temperature (primary)	70°C (current)	Onsite observations
	55°C (future minimum)	Minimum proposed flow temperature following WP3 works
DHW set point	50 °C	CP1 2020
Bath outlet temperature	45 °C	Typical value observed on similar sites
Shower outlet temperature	45 °C	Typical value observed on similar sites
Cold water temperature	10 °C	Typical value observed in winter months
DHW diversity	-	DH439 flow rate diversity
Space heating demand	65 W/m^2	Typical value based on building age (see Appendix 6 - Space heating temperature calculation methodology)
Space heating diversity	-	CP1 2020 methodology

Table 32: Peak load calculation inputs and assumptions

13. Appendix 6 - Space heating temperature calculation methodology

The following section sets out the methodology for estimating the radiator operating temperatures required to meet the space heating demand in dwellings at Meakin Estate.

From FairHeat's experience, 35 W/m^2 is the expected heat load of a new-build residential development. Meakin Estate is c. 30-40 years old, so a heat load of 65 W/m^2 has been assumed as the requirement within dwellings, as fabric efficiency requirements have increased in this time.

During the site audits, the floor areas and radiator sizes were recorded in all 4 dwellings to enable the heat demand to be calculated for each room. The output of each radiator is assumed to be equivalent to that of the BS EN 442 Stelrad Elite radiator output of the same or closest available size that information is available for.

The radiator output at potential future operating conditions can be calculated using the calculation below. This can be used to determine whether or not the output being delivered to each room can meet the losses of the building fabric in that room.

$$P = P_{50}\left[\frac{(T_i - T_r)}{\ln\left(\frac{T_i - T_a}{T_r - T_a}\right) \times \frac{1}{49.32}}\right]^n$$

In this equation, P is the heat emitter output (W), P_{50} is the heat emitter output from the radiator with a 50°C temperature difference (W), T_i is the inlet temperature (°C), T_a is the ambient temperature (°C), T_r is the outlet temperature (°C), and n is the constant for the type of radiator (varying between number of convectors and panels, defined by manufacturer).

Following analysis using this methodology, it was determined that a temperature profile of 65/50 °C ensures the radiator output not more than 5% below the estimated room demand.

Within Work Package 3, radiator replacement, PHE removal and single-plate HIU retrofit works are to be conducted, which will enable the new radiators to operate at a reduced temperature profile of 55/40 °C.

14. Appendix 7 – Techno-economic appraisal assumptions

14.1. Capital Costs

The capital costs have been determined through the use quotes from other similar heat network projects that FairHeat has recently been involved with. FairHeat design, engineering support and delivery costs have been estimated using previous project costs. An uplift of 10% has been added to all costs to account for preliminaries, as well as 15% for principal contractor markups, and 15% for consultancy markups and preliminary costs. Uplifts of 3.5% and 10% have also been included for inflation and contingency. It should be noted that these costs are not finalised and are subject to change if the work packages are pursued.

It is assumed that dwelling works incur a cost. However, these costs may be covered within the current dwelling maintenance contract, in which case the cost of all work packages would reduce.

14.1.1. Exclusions

It should be noted that, throughout the techno-economic analysis, the following items have not been included, but shall be considered prior to and during any works conducted as a result of this study:

- Cold water system design or specification
- Wider electrical works not related to heat network upgrades.
- Structural loads or system supporting design (pipework, plinths etc.)
- Power, electrical, acoustic & ventilation design or specification
- Detailed pipework support system and expansion design
- All items related to Fire and Gas Safety (e.g. temporary and permanent firestopping)

14.1.2. Work Packages

The estimated costs associated with the performance improvement works are shown below in Table 33.

Work process	Unit cost (£)	Work Package			Source/assumptions
		1	2	3	
Dwelling					
Recommission/balance radiator circuit	25	X			Costed from previous experience of similar works
Close and remove space heating bypasses within dwellings	150	X			Costed from previous experience of similar works
Insulate terminal pipework	150	X	X	X	Costed from previous experience of similar works
Install PI-TRVs on all radiators	90		X	X	Costed from previous experience of similar works
Replace heating thermostats/programmers	200		X	X	Costed from previous experience of similar works
Install single-plate HIUs (with AMR metering)	3,000		X	X	Costed from previous experience of similar works
Replace radiators[1]	250			X	Costed from previous experience of similar works
Network					
Close and remove network bypasses (excluding index dwellings)	100	X			Costed from previous experience of similar works
Install/recommission TCVs on DHW recirculation loops	700	X			Costed from previous experience of similar works
Reinsulate network pipework	40 /m	X	X	X	Costed from previous experience of similar works
Decommission space heating pipework and repurpose DHW pipework for 2-pipe system	25,000		X		Costed from previous experience of similar works

Decommission all secondary network pipework and retrofit new combined pipework[2]	6,000 /floor (risers) 300 /m (laterals)			X	Costed from previous experience of similar works
Substation					
Recommission DHW 3-port control valve	1,600	X			Costed from previous experience of similar works
Recommission DHW calorifier set point to 60°C	200	X			Costed from previous experience of similar works
Reinsulate substation pipework	40 /m	X	X	X	Costed from previous experience of similar works
Decommission DHW calorifiers and replumb LTHW pipework	10,000		X	X	Costed from previous experience of similar works
Remove substations (PHEs)	11,000			X	Costed from previous experience of similar works
Plant room					
Reinsulate plant room pipework	40 /m	X	X	X	Costed from previous experience of similar works
Reinstate BMS and controls strategy	4,000	X	X	X	Costed from previous experience of similar works
Recommission network and shunt pumps	1,200	X	X	X	Costed from previous experience of similar works
Replace network pumps	16,000		X	X	Costed from previous experience of similar works
Replace dosing pot with side-stream filtration unit	8,000		X	X	Costed from previous experience of similar works
Replumb boilers to reverse return arrangement	2,000		X	X	Costed from previous experience of similar works

Recommission boiler set point to 70°C	200	X	X		Costed from previous experience of similar works
Reduce boiler set point to 55°C	200			X	Costed from previous experience of similar works
Replace boilers[1]	85 /kW			X	Costed from previous experience of similar works
Install network 3-port valve	12,000			X	Costed from previous experience of similar works
Split low loss header, install buffer vessel and replumb pipework	27,000			X	Costed from previous experience of similar works
Project support					
Prelims	10%	£20,290	£65,640	£136,000	Added percentage
Project management	-	£56,070	£68,970	£94,770	FairHeat cost estimate
Design	-	£18,000	£45,500	£62,000	FairHeat cost estimate
Engineering support	-	£30,000	£60,000	£80,000	FairHeat cost estimate
Uplifts					
Principal Contractor markup	15%	£30,440	£98,460	£204,000	Added percentage
Principal Contractor consultancy markup	15%	£10,240	£25,670	£41,700	Added percentage
Inflation	3.5%	£11,460	£31,380	£60,640	Added percentage
Project Contingency	10%	£37,950	£105,200	£203,900	Added percentage

Table 33: Performance improvement capital costs. [1]Radiator and boiler replacements are not eligible for external funding via HNES (see Section 6.2.3). [2]This item includes an allowance for builder's works.

14.1.3. Replacement Costs (REPEX)

Given FairHeat's previous experience on other projects, the age of the Meakin Estate network and issues with the secondary pipework seen during the site audit, the plastic secondary pipework is likely to fail within the next 2-3 years. As such, is has been estimated that, if decommissioning and replacement of this pipework is not carried out, a full network retrofit will be required in the next 2-3 years.

Due to the condition of the BMS and combined low loss header and air/dirt separator during the site audit, these pieces of equipment are likely to fail within the next 5-10 years. Consequently, FairHeat have estimated that if the BMS is not reinstated and an air/dirt separator is not installed (separate to the low loss header), both items will likely need a replacement within 5-10 years from now.

Also, since the substation heat meters were not operational during the site visit, new heat meters will need to be installed in the first year of works, if they are not fixed as part of the risk mitigation works (see Section 14.1.5).

For each piece of equipment, this replacement expenditure has not been modelled in the NPV for work packages where that piece of equipment is due to be repaired, replaced or removed. These scenarios have been detailed in Section 6.2.2 and in Table 34 below.

Item	Replacement start year	Replacement end year	Replacement cost	Totals			
				Base Case	WP1	WP2	WP3
Heat meters	1	1	£1,500	4	0	0	0
Plastic space heating pipework	2	3	£466,500	1	1	0	0
Plastic DHW pipework	2	3	£466,500	1	1	1	0
BMS	5	10	£50,000	1	0	0	0
Combined LLH & ADS	5	10	£10,000	1	1	1	0
Replacement cost (£/Work Package)				**£999,000**	**£943,000**	**£476,500**	**£0**

Table 34: Replacement costs for Base Case and Work Packages 1 and 2

14.1.4. Sinking Fund Costs

The network pumps are being replaced and the DHW calorifiers, 2 of the 4 expansion vessels and 8 of the 12 substation pumps are being removed in Work Package 2. In Work Package 3, the boilers and shunt pumps are being replaced, whilst the substation PHEs and all substation pumps are being removed. This means that, in each case, Leathermarket JMB do not need to contribute to end of life replacement of this equipment. As such, this has been accounted for in the Base Case and each Work Package. Table 35 details the annualised sinking fund contributions for each item of equipment.

Item	Equipment lifespan (CIBSE Guide M)	Lifetime replacement cost	Equipment number	Annualised sinking fund contributions			
				Base Case	WP1	WP2	WP3
Boilers	20	£55,088	2	£5,509	£5,509	£5,509	£0
Network pumps	20	£8,000	2	£800	£800	£0	£0
Shunt pumps	20	£7,500	2	£750	£750	£750	£0
DHW calorifiers	20	£7,800	4	£1,560	£1,560	£0	£0
PHEs	15	£15,000	4	£4,000	£4,000	£4,000	£0
Secondary pumps	20	£4,000	12	£2,400	£2,400	£800	£0
Expansion vessels	20	£5,000	4	£1,000	£1,000	£500	£500
Total annual sinking fund contribution (£/Work Package)				**£16,019**	**£16,019**	**£11,559**	**£500**

Table 35: Sinking fund costs for the plant room equipment

14.1.5. Water quality and risk mitigation works

The estimated costs associated with the works presented as other considerations are shown below in Table 36.

Item	Unit cost	Source/assumptions
Fix substation heat meters	£230	Costed from previous experience of similar works
Install TMVs on bath outlets	£173	Costed from previous experience of similar works
Install quick fill loop on cold water connection in plant room	£2,300	Costed from previous experience of similar works
Decommission and remove 2 expansion vessels in plant room	£4,600	Costed from previous experience of similar works
Install air and dirt separator in plant room	£6,900	Costed from previous experience of similar works

Table 36: Cost of works that are presented as other considerations rather than performance improvements

14.2. Heat loss model

To enable comparison between the work packages, the network heat losses have been calculated using the ISO 12441 heat loss from pipework calculation methodology.

All work package specific assumptions are detailed below.

Pipework sizing

- All pipe sizes assumed to be installed as per design, which is consistent with observations on site
- Medium grade steel pipework installation in the plantroom, primary (buried) network and in secondary network roof voids, copper pipework for terminals and plastic pipework installation throughout the rest of the secondary DHW and space heating networks
- Riser length of 3.15 m per floor
- Terminal run length of 5 m and terminal drop length of 1.5 m

Ambient temperatures

- 10 °C for external lateral pipework
- 20 °C for all other internal pipework

Insulation consistency and type

- The plantroom, supply and riser insulation coverages are based on on-site observations
- In the Base Case and all Work Packages, it is estimated that 50% of the total terminal pipework length is accessible. It has been assumed that inaccessible pipework is uninsulated. In all Work Packages, reinsulation works are proposed across the entire network, where the accessible portion of the riser, lateral and terminal run/drop pipework insulation will be upgraded to Phenolic Kooltherm insulation.
- In all cases where an insulation upgrade has been made to Phenolic Kooltherm, the chosen thickness is 30 mm, except along terminal drop pipework and for large pipework (≥DH65 in size), where 25 mm and 50 mm is proposed respectively. This is the thickest insulation that would be reasonably practicable to install in each location, based on on-site observations.
- The heat losses from the DHW calorifiers in the substations are assumed to be 150 W (Substations 1-3) or 270 W (Substation 4) per cylinder in the Base Case and Work Package 1. In Work Packages 2 and 3, the heat losses from the HIUs are assumed to be 32 W per HIU, based on typical test results from the BESA UK HIU Test Regime.
- For the Base Case, Work Package 1 and 2, the heat losses from the substation PHEs are estimated to be 384 W (Substations 1-3) or 475 W (Substation 4) per PHE. These were determined using heat loss data from Danfoss for PHEs and calculations of the PHE external surface areas.

	Plant room	Supply/ Buried	Riser	Lateral	Terminal run/drop
Base Case					
Insulation	Mineral wool 20-50 mm	Mineral wool 20-50 mm	Mineral wool 20-25 mm	Armaflex 15-20 mm	Uninsulated
Coverage	90%	90%	80%	70%	0%
Work Package 1					
Insulation	Kooltherm 30-50 mm	Kooltherm 30-50 mm	Kooltherm 30 mm	Kooltherm 30 mm	Kooltherm 25 mm
Coverage	98%	98%	90%	90%	50%
Work Package 2					
Insulation	Kooltherm 30-50 mm	Kooltherm 30-50 mm	Kooltherm 30 mm	Kooltherm 30 mm	Kooltherm 25 mm
Coverage	98%	98%	90%	90%	50%
Work Package 3					
Insulation	Kooltherm 30-50 mm	Kooltherm 30-50 mm	Kooltherm 30 mm	Kooltherm 30 mm	Kooltherm 25 mm
Coverage	98%	98%	90%	90%	50%

Table 37: Insulation type and consistency used in heat loss calculations for the Base Case and for the Work Package scenarios

<u>Temperatures for heat loss calculation estimates</u>

- The Base Case temperatures are based on on-site observations and heat meter data
- Work Package flow temperatures are chosen to ensure that the flow temperature is sufficient to ensure all radiators can meet the required space heating load as calculated in Appendix 6 - Space heating temperature calculation methodology.
- In Work Package 1, network flow and return temperatures decrease due to the removal/recommissioning of network bypasses and recommissioning works for the plant room boilers and pumps, as well as the substation calorifiers.
- In Work Package 2, additional reductions in return temperatures are achieved because of the proposed 4-pipe to 2-pipe network conversion, DHW calorifier and network decommissioning and HIU retrofit within all dwellings and the community centre.
- In Work Package 3, the network flow and return temperatures decrease even further due to boiler replacement, low loss header removal and thermal store installation/replumbing works in the plant room, decommissioning of the PHEs in each substation, as well as radiator replacements in all dwellings and the community centre.

Network section	Base Case		WP1		WP2		WP3	
	Flow temp (°C)	Return temp (°C)	Flow temp (°C)	Return temp (°C)	Flow temp (°C)	Return temp (°C)	Flow temp (°C)	Return temp (°C)
Plant room	71	63	70	60	70	60	55	40
Supply/ Buried	68	61	70	60	70	60	55	40
Riser*	56	52	60	50	60	50	52	38
	54	50	65	50				
Lateral*	56	52	60	50	55	45	48	38
	54	50	65	50				
Terminal run/drop*	56	52	60	50	45	40	42	36
	54	50	65	50				

*Table 38: Flow and return temperatures used in heat loss calculations for the Base Case and for the Work Package scenarios. *The first row indicates DHW and the second row is for space heating in the Base Case and Work Package 1 where there is a partial 4-pipe system (excluding plant room and supply/buried pipework, where it is 2-pipe)*

14.3. Heat consumption

Typically, a total average demand of 2,920 kWh/dwelling/year is assumed based on the BESA UK HIU Test Regime. However, a dwelling heat consumption of 6,000-13,600 kWh/dwelling/year has been assumed for the Base Case and Work Package 1. This is based on typical dwelling gas usage from Ofgem and assumes a gas boiler efficiency of 80%, given the age and condition of the Meakin Estate heat network compared to a typical New Build. With the works proposed in Work Packages 2 and 3, this is expected to fall in line with the BESA demand assumption and has been modelled as such.

Based on the network heat losses calculated, typical boiler efficiencies and gas prices, and assuming that 50% of terminal drop and HIU losses can be considered for useful gain for 30% of the year, the gas consumption, efficiency and required tariff for the base case and work packages can be estimated, which is shown in Table 39.

	Base Case	WP1	WP2	WP3
Total heat consumption (kWh/year)	716,900	724,000	350,100	350,700
Total heat loss (kWh/year)	1,080,800	650,600	297,900	237,900
Generation efficiency (%)	80%	80%	80%	90%
Gas consumed (kWh/year)	2,247,100	1,718,300	810,000	654,000
Overall generation & distribution efficiency (%)	32%	42%	43%	54%

Table 39: Calculated network efficiencies and required heat tariffs

14.4. Pump energy consumption

Estimated power consumptions have been calculated for all pumps and modelled for the work packages and are shown in Table 40.

For pumps operating under variable flow conditions, the load profile from an existing scheme has been used to determine the pump energy consumption. In the load profile used, the pump operates for 69.7% of the year at less than 25% load, 22.9% of the year between 25% and 50% load, 6.0% between 50% and 75% load, and 1.4% of the year above 75% load.

Pump energy has been assessed at each load using index run pressure losses, with the total annual consumption calculated using the load profile.

	Base Case	WP1	WP2	WP3
Network pumps	52,560	4,107	1,226	2,564[1]
Boiler shunt pumps	21,900	969	969	969
Substation space heating pumps	12,965	2,326	3,844[2]	0
Substation DHW pumps (primary flow)	7,490	1,365	0	0
Substation DHW pumps (secondary return)	8,760	8,760	0	0
Substation DHW recirculation pumps	1,752	1,352	0	0
Total (kWh/year)	**105,427**	**18,879**	**6,039**	**3,533**

Table 40: Pump energy consumption calculation assumptions. [1]Substation PHEs are due to be removed in WP3, leading to a higher required network pump dP. [2]4-pipe to 2-pipe network conversion proposed in WP2, with space heating pumps repurposed as secondary LTHW pumps

14.5. Gas and electricity costs

The year 1 gas and electricity costs used within the NPV calculations are shown in Table 19.

To adjust for changes in natural gas and electricity tariff, the year 1 prices have been adjusted by a factor based on HM The Green Book: Central Government Guidance on Appraisal and Evaluation. Gas and electricity costs are assumed to rise as expected by the "Commercial / Public Sector costings price index" tariff.

The calculated electricity and natural gas factors used are shown in Table 41.

Year	Cost factor[1]		Predicted tariff (p/kWh)	
	Natural gas	Electricity	Natural gas	Electricity
2024	1.000	1.000	15.24	46.72
2025	0.672	0.539	10.24	25.20
2026	0.629	0.475	9.58	22.18
2027	0.585	0.394	8.92	18.40
2028	0.542	0.373	8.25	17.45
2029	0.498	0.353	7.59	16.52
2030	0.497	0.355	7.57	16.57
2031	0.495	0.346	7.55	16.16
2032	0.494	0.334	7.53	15.61
2033	0.493	0.323	7.51	15.08
2034	0.492	0.322	7.49	15.06
2035	0.491	0.322	7.47	15.06
2036	0.489	0.311	7.46	14.52
2037	0.488	0.313	7.44	14.64
2038	0.487	0.316	7.42	14.79
2039	0.486	0.315	7.40	14.73
2040	0.486	0.316	7.41	14.77
2041	0.487	0.319	7.41	14.88
2042	0.487	0.314	7.42	14.67
2043	0.487	0.313	7.43	14.63

1 – Factors assume natural gas and electricity cost increase follows the Commercial / Public Sector costings price index

Table 41: Energy cost factors – (HM The Green Book: Central Government Guidance on Appraisal and Evaluation, high energy cost scenario)

14.5.1. Gas and electricity cost of carbon

The cost of carbon emissions has not been accounted for in the NPV calculations. However, it is worth noting the increase in the cost of carbon in the coming years.

Carbon costs and grid carbon intensity data has been taken from *'Green Book supplementary guidance: valuation of energy use and greenhouse gas emissions for appraisal'.* The cost of carbon below is based on the 'Central' scenario.

This data, and the resulting cost per kWh of natural gas burnt and electricity consumed, is shown below in Table 42.

Year	Cost of Carbon[1] (£/tonne C02e)	Carbon intensity (kgC02e/kWh)[1]		Carbon cost (£/kWh)	
		Natural gas	Electricity	Natural gas	Electricity
2024	£256	0.216	0.138	£0.061	£0.039
2025	£260	0.216	0.120	£0.062	£0.034
2026	£264	0.216	0.090	£0.063	£0.026
2027	£268	0.216	0.067	£0.064	£0.020
2028	£272	0.216	0.058	£0.065	£0.017
2029	£276	0.216	0.049	£0.066	£0.015
2030	£280	0.216	0.045	£0.067	£0.014
2031	£285	0.216	0.038	£0.068	£0.012
2032	£289	0.216	0.030	£0.069	£0.010
2033	£293	0.216	0.024	£0.070	£0.008
2034	£298	0.216	0.019	£0.071	£0.006
2035	£302	0.216	0.018	£0.072	£0.006
2036	£307	0.216	0.018	£0.073	£0.006
2037	£312	0.216	0.017	£0.074	£0.006
2038	£316	0.216	0.016	£0.075	£0.006
2039	£321	0.216	0.015	£0.077	£0.005
2040	£326	0.216	0.015	£0.078	£0.005
2041	£331	0.216	0.014	£0.079	£0.005
2042	£336	0.216	0.013	£0.080	£0.005
2043	£341	0.216	0.008	£0.081	£0.003

1 – HM The Green Book: Central Government Guidance on Appraisal and Evaluation, cost of 1 tonne of carbon emission and predicted carbon factor per year for 20 years

Table 42: Cost of carbon for electricity used

14.6. Maintenance costs

Plant room and dwelling reactive maintenance costs have been estimated based on the maintenance logs and costs provided by Leathermarket JMB.

Planned dwelling maintenance costs have been estimated assuming 15% of callouts from reactive dwelling maintenance per year require re-organised visits.

Maintenance management and labour costs have been estimated using reactive maintenance data provided by Leathermarket JMB and some assumptions: each callout lasts 15 minutes and 1 in 10 callouts results in a resident complaint.

These costs have been decreased accordingly in work packages where equipment has been controlled in the plant room and substations or where dwelling reliability has been increased via HIU installation. Work Packages 1, 2 and 3 have been assumed to reduce maintenance frequency (in plant room, substations and dwellings) by 15%, 60% and 95% respectively.

The results of this analysis are summarised in Table 43.

Cost	Base Case	WP1	WP2	WP3
Plant room – Reactive (£/annum)	£2,565	£2,180	£1,026	£128
Dwelling – Planned (£/dwelling/annum)	£8	£4	£2	£0
Dwelling – Reactive (£/dwelling/annum)	£53	£27	£13	£2
Management of maintenance (£/annum)	£7,448	£3,824	£1,799	£225
Labour cost of responding to complaints (£/annum)	£98	£83	£39	£5
Total (£/annum)	**£22,974**	**£18,803**	**£10,470**	**£2,952**

Table 43: Estimated planned and reactive maintenance costs

15. Appendix 8 – KPI glossary

15.1.1. Energy centre KPIs

- Heat generation efficiency – the efficiency with which the heat generation equipment (e.g. gas boilers) produce heat for the network, measured using gas/electricity and heat meter data.
- Average flow temperature – the average flow temperature provided to the network from the plant room, measured from heat meter data.
- Average return temperature – the average return temperature from the network to the plant room, measured from heat meter data.

15.1.2. Heat network KPIs

- Heat network loss – the standing heat losses from the network, measured using plant room and dwelling heat meter data or a model.
- Bypass flow rate – the percentage of flow leaving the plant room that is not used to serve dwellings, measured using plant room and dwelling heat meter data.
- Average flow temperature – the average flow temperature provided to the network, measured using block level heat meter data.
- Average return temperature – the average return temperature from the network/each block, measured using block level heat meter data.

15.1.3. Dwelling KPIs

- VWART during DHW delivery – the volume weighted average return temperature from dwellings during DHW delivery, measured using dwelling heat meter data.
- VWART when no demand (i.e. standby) – the volume weighted average return temperature from dwellings during standby periods, measured using dwelling heat meter data.
- VWART during space heating – the volume weighted average return temperature from dwellings during space heating delivery, measured using dwelling heat meter data.
- Average VWART across all modes of operation – the volume weighted average return temperature from dwellings, measured using dwelling heat meter data.

15.1.4. Reliability or financial KPIs

- Time below minimum flow temperature – the amount of time (hrs) per annum that the network is operating below the sufficient flow temperature to deliver heat to residents, measured using heat meter data.
- Flow temperature stability – the percentage of time the network operates within ±3 °C of the flow temperature set point, measured using heat meter data.
- Major outages – the number of times per 100 days that the flow temperature or differential pressure has fallen below minimum for over 4 hours or any other issue leading to >10% of residents not receiving heat for over 4 hours.

- VWAFT – the volume weighted average flow temperature to the network, measured using heat meter data.
- Reported interruptions and reductions – the number of reported interruptions or reductions per 100 dwellings per 3-month period.
- Maintenance frequency – the number of O&M visits to dwellings per 100 dwellings per 3-month period.
- Year 1 required heat tariff – the cost of energy used to generate the heat required to supply dwellings. This includes heat lost during transmission and reflects the efficiency of heat generation and the distribution network. It does not account for the maintenance costs or pump electricity consumption.

15.1.5. Carbon intensity KPI

- Carbon intensity of heat delivered – this reflects the carbon emissions associated with each unit of heat consumed by the end user. The metric considers only operational carbon associated with network energy consumption. The carbon intensity of heat can be used to compare the environmental performance of different systems and will be an important metric in scenarios where organisations have net zero carbon targets. Note that to use this metric effectively assessors should ensure that the carbon factors within the calculation are clearly identified.

16. Appendix 9 – RFI list

RFI	Provided?	Detail
Mechanical services spec	Yes	From network refurbishments in 2016
Plant room LTHW schematic	Yes	-
Network LTHW schematic	No	Pipework distribution layouts provided
Dwelling LTHW / tertiary services schematic	No	-
Site layouts	Yes	-
Plant room layouts	No	Drawings made during site audit
Network layouts	No	Only sitewide
Dwelling layouts	Yes	-
Plant room equipment schedule	No	-
Dwelling equipment schedule	No	-
Accommodation schedule/number of units	Yes	-
Plot to postal schedule	Yes	-
Installed equipment and O&M docs	No	-
Previous logs outlining the maintenance contractor/arrangements works	Yes	Maintenance log and costs provided from January 2023–January 2024
Previous records and logs of resident complaints pertaining to the heating/hot water	No	No complaints data, only reactive maintenance
Gas meter data	Yes	Gas invoice data from April 2023-March 2024
BMS data	No	-
Heat meter data	No	Limited heat metering across network, with no dwelling-level metering
Discount rate	No	Assumed at 3.5% (public body)
Gas price	Yes	Provided by Southwark council
Electricity price	Yes	Provided by Southwark council

Table 44: Site information provided in response to RFI